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Aeronautical Engineering REVIEW

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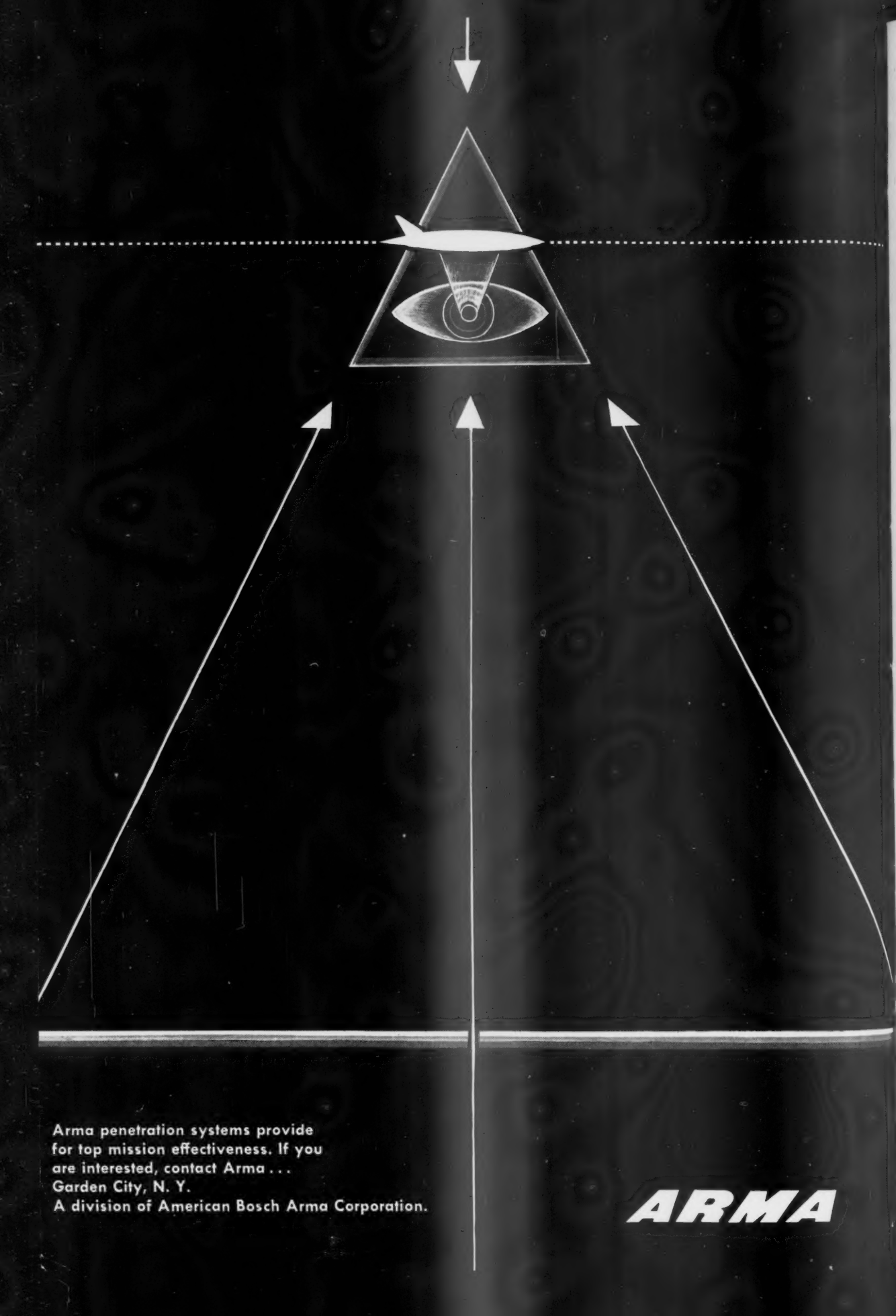

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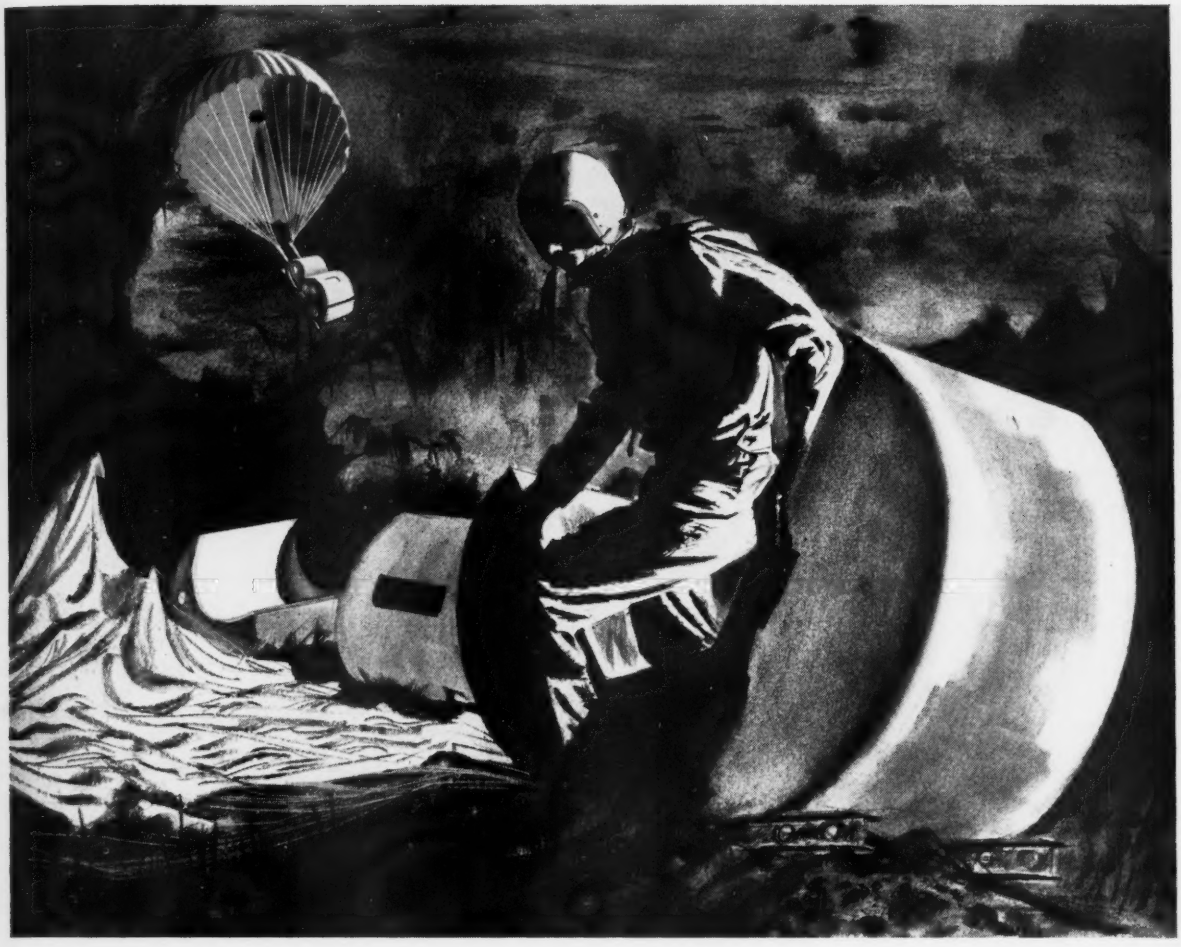

SPECIAL DELIVERY *of an Airman In Trouble*

A FEW YEARS AGO, this jet pilot would never have lived to tell the story.

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Aeronautical Engineering REVIEW

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Cover—Republic Aviation Corporation's RF-84F Thunderflash is a photo-reconnaissance fighter in the 650 m.p.h. class. This jet has a range of 2,000 miles, but, when "hitched" to a GRB-36 aerial carrier plane, its range is extended by the 10,000-mile range of the "mother" plane. Armed with 0.50 cal. machine guns, the Thunderflash is equipped for high or low altitude, day or night reconnaissance. The training mission pictured was snapped with an aerial camera in another Thunderflash.

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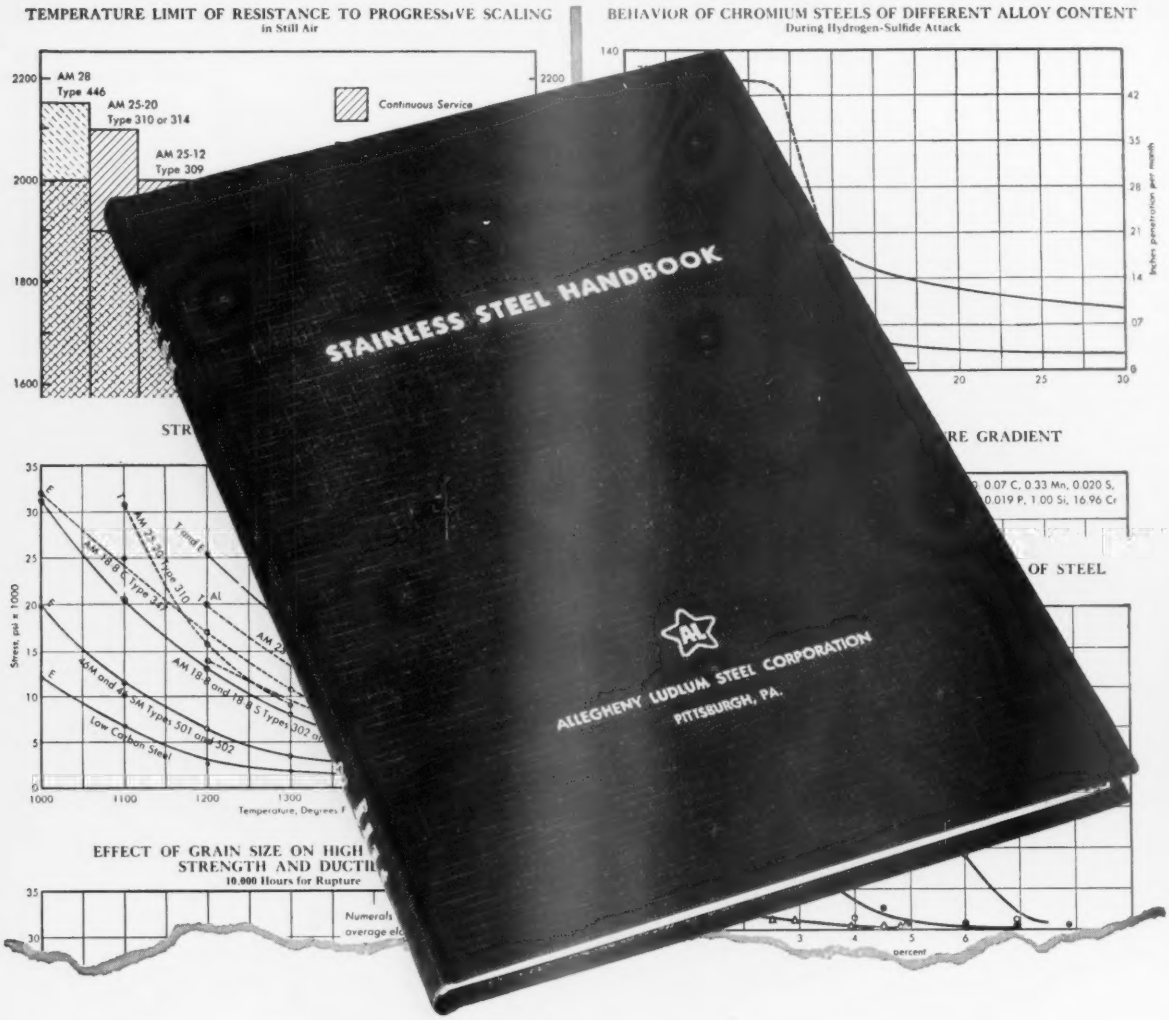

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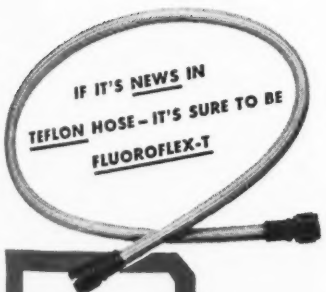

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Why reliability engineering is not enough

There's more to reliability than meets the eye . . . a thousand inspectors cannot put reliability into an item that is inherently weak in engineering or production design . . . highest reliability in a component is obtained only when the manufacturer is aware of the problems in obtaining reliability . . . plus providing a proper climate in which employees are motivated by pride in product to surpass specifications.

In our humble opinion, the building of reliability into a product requires an alert *awareness* of the many, many facets of the problem. We'd like to submit these . . .

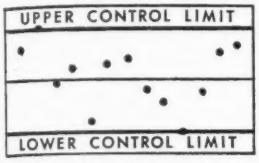
- ***"Integrity of intent" on the part of the manufacturer to meet the problems . . . coupled with provision of a proper climate for the carrying out of reliability objectives***
- ***Financial ability to take the necessary steps***
- ***Modern manufacturing equipment and methods***
- ***Plant capacity and flexibility***
- ***Design and engineering know-how that recognizes end-use requirements and environmental conditions***
- ***Careful employee selection and training***
- ***Long-range master planning***
- ***In-plant industrial and production engineering***
- ***Research, testing, development laboratory activities, including complete testing of prototype to end-use requirements***
- ***Continuous reliability assurance testing during the manufacturing operation, and institution of required corrective action***
- ***Collection, in the field, of failure data, analysis, and corrective action***
- ***All of these facets in depth***

Important as all of these are, the most important is the provision of proper climate, in the form of spirit and attitude of all personnel in pride of product, to carry out reliability objectives. In preceding articles in this series we've touched on some of the more technical aspects of reliability engineering. The manufacturer must naturally have an awareness of the problem, the integrity of intent to turn out the best product it can for a particular market or application, the financial ability to establish a Reliability program, the management ability to install it, the necessary manufacturing equipment and engineering organization to carry it out. But *all of these are not enough, if they are not instituted in a climate where an attitude will prevail that makes such things effective.*

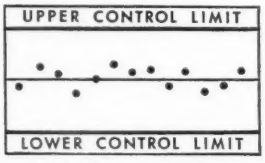
The manufacturer's integrity must necessarily be carried out, also, in the design, in manufacturing, and in finally warranting the product created . . . but, again, with every man and woman in the organization trying to meet or exceed the standards that have been created. This latter aspect we call "pride of product" on the part of the people who are producing it. And such pride must exist not only for the final product but for each part of that product, and in each step in the process. There is also an added dividend to reliability; the reputation of the product will cause the user to handle it with the same pride and care as was put into its manufacture.

It is interesting that people who are proud of a product, and enjoy what they are doing, can keep closer tolerances on the parts they work with and produce than those who are merely working for their pay. An assembler, who's proud of the product turned out, sees questionable components and avoids putting them into the assembly, while a disinterested person leaves them for "inspection" to catch. It is interesting in this connection, too, that some of the finest watch

parts made in Switzerland are produced in little shops where modern quality control techniques are unheard of . . . produced by a craftsman whose major technique is pride in his work . . . and thereby builds everything to the exacting tolerances required.



Quality control graph . . . without pride in product.



Quality control graph . . . with pride in product.

The atmosphere here at Cannon, since our inception in 1915, has included a design and manufacturing philosophy embracing the highest quality and reliability in each Cannon Plug for the specific application for which it is to be used. *To these principles all Cannon Plugs are built*! Even on connectors designed to customer or MIL-spec we constantly strive to give even more . . . to increase the safety factor . . . to give that "something extra" according to our own high "Cannon Standards", as exemplified in our Cannon Credo.

THE CANNON "CREDO"

TO DEVELOP *an organization of exceptional people possessed of respect for the dignity of the individual and imbued with the spirit of the team.*

TO PROVIDE *a facility with which we can produce to our utmost in an efficient and pleasant environment.*

TO DEVELOP *and produce products of such quality, and render such service, that we may always be proud of our efforts.*

TO MARKET *the product of our endeavor at a reasonable profit for continuing growth, reward for effort and a return on investment.*

TO ACCEPT *our responsibility to our community, our country, and our fellow man.*

The Cannon "Credo" is posted through all departments of all Cannon plants . . . Copy available to you on request.

On the more technical side . . . we at Cannon have attempted not only to provide the proper climate for a complete reliability program from the viewpoint of mental attitude, but to provide the necessary facilities in which that attitude may work effectively. One of the most important of such fields is that of engineering organization and proper utilization of specialized engineering personnel. As a purchaser of Cannon Plugs, with a personal stake in their reliability, you will be interested to know that our engineering divisions are grouped as follows:

Master Planning Group . . . men who look to the future . . . investigating the newest in technological improvements, providing interplant project coordination for maximum flexibility to meet the challenges of our ever-changing future.

Industrial Engineering Group . . . experts who call out the materials, methods, and processes to be used in the manufacturing cycle . . . experts who collect, analyze, and institute corrective action in accordance with field failure data.

Sales Engineers . . . fully qualified technical men who contact our customers.

Design Engineers . . . specialists in past and present design methods who analyze failure data caused by design inadequacies and initiate corrective action.

Development Engineering and Model Shop Group . . . specializing in the development of prototypes. In these Laboratories, your prototype is tested to see that all specifications are met . . . physical, operating, environmental. Test reports are made up, and presented to you for review and approval. Not until all these steps have been taken is your order placed in production.

Product Engineers . . . specialists in particular types of connectors.

Quality Control Group . . . well qualified to administer the high requirements of "Cannon Standards" . . . staffed by well trained inspectors and analysts equipped with the most modern equipment.

Quality Engineering Group . . . handling the technical aspects of sampling plans . . . preparing inspection and test procedures to realize the customer's desired quality level and the over-all quality level of the entire Cannon manufacturing operation. Materials are processed through receiving inspection. Process, re-work and final inspection barriers are set up. In addition to standard Military and Cannon manuals of quality control procedures, specific jobs . . . such as yours . . . may require additional special inspection or testing. If so, these requirements are established throughout the process, and where necessary, coordinated with you. Our failure data collection and analysis in this field has given us intimate knowledge of the critical points at which such control should be used. Recognized statistical control procedures are used both in process and at the inspection points.

Materials and Processes Laboratory Group . . . working in both the research and production phases. This is the group that checks performance of new designs, constantly investigates new materials and processes, and (over and above normal manufacturing supervision and quality control operation) runs continuous reliability and assurance tests on the manufacturing cycle.

* * *

Each of our 20,000 Standard Cannon Plugs are of highest quality and were designed to meet exacting reliability requirements. We also produce special designs to meet the most exceptional AQL end-use requirements.

If you have a problem requiring high-reliability Cannon Plugs, we would appreciate the opportunity working with you.

Cordially,

Robert J. Cannon *President*

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STAFF COMPUTER ENGINEERS

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The adaptation of established analog computational techniques to the design of a permanent custom-built system for the simulation of a particular aircraft is the fundamental responsibility of our Engineering Division.

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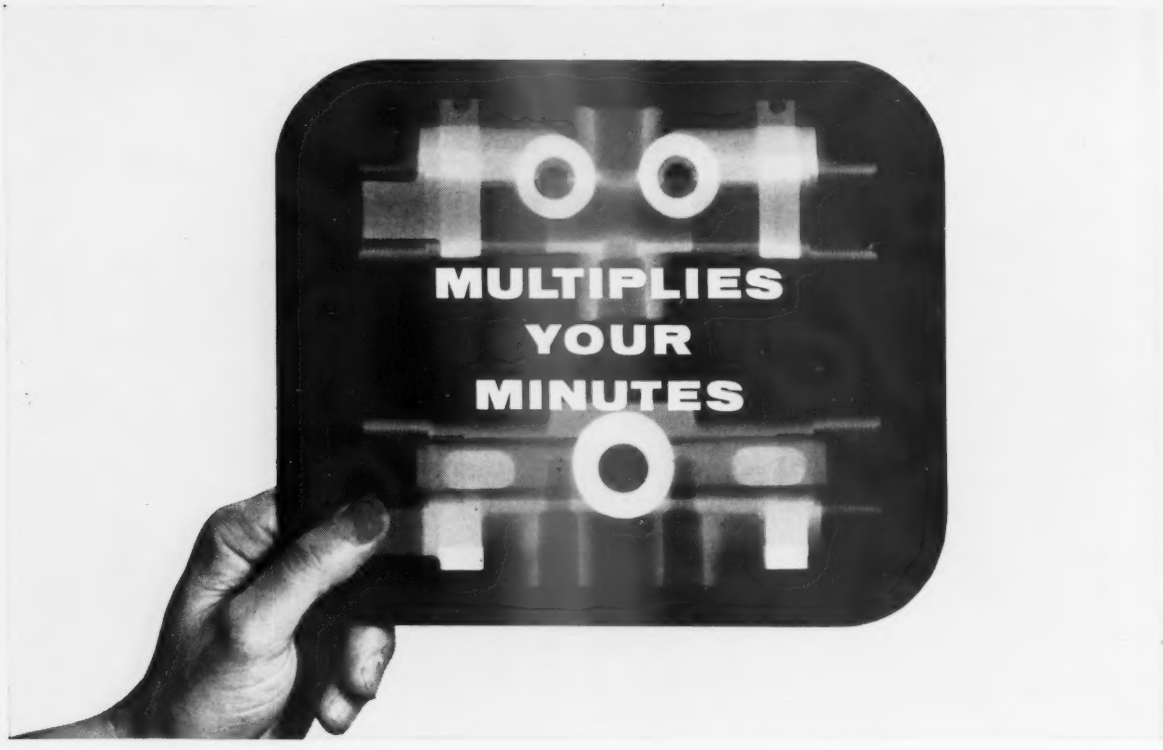
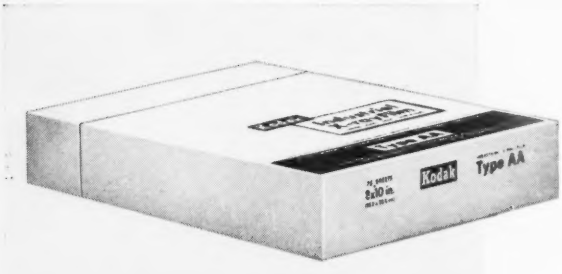


New Kodak Industrial X-ray Film, Type AA



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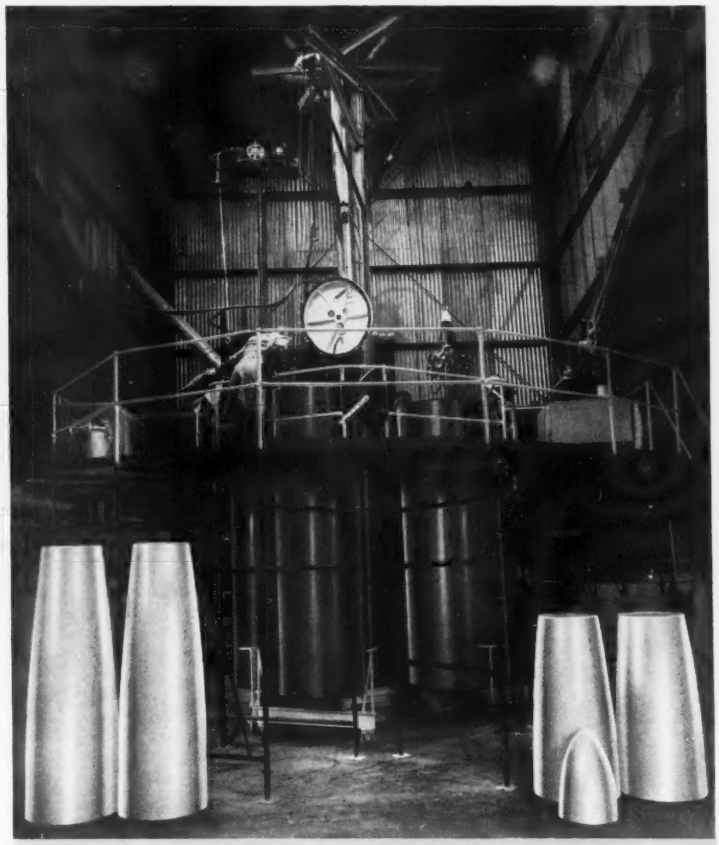

Now, after five and one-half years of persistent development, uniformly controlled shapes of highest quality and strength at low mass cost.

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*GFR MEANS GLASS, FIBER, RESIN

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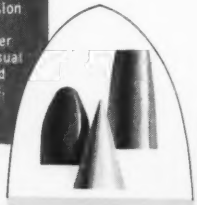

Pastushin high-uniformity radomes are being developed beyond the prototype stage.

Among GFR shapes in production are containers ten ft. long and 44 in. in diameter (with even larger possible), for storing and transporting missiles and other material.

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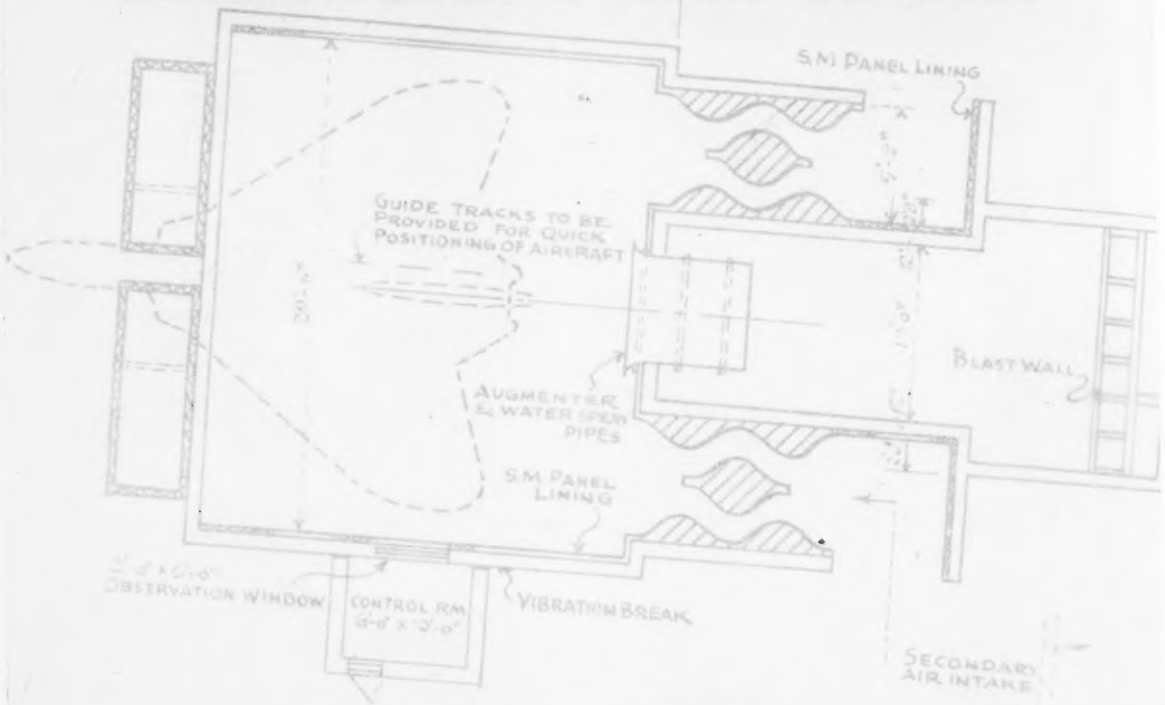

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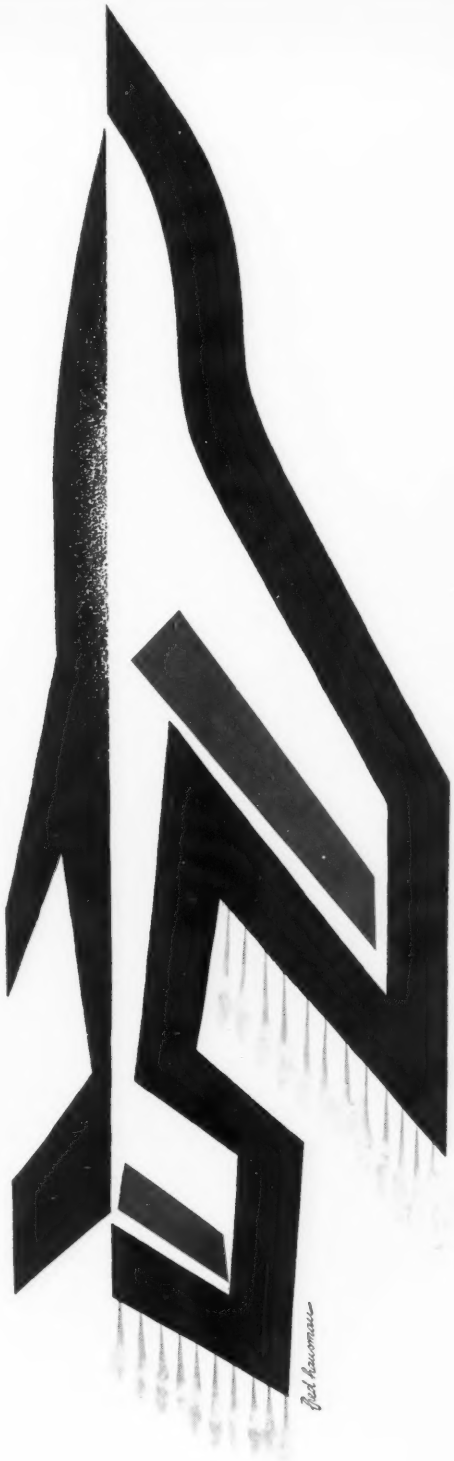
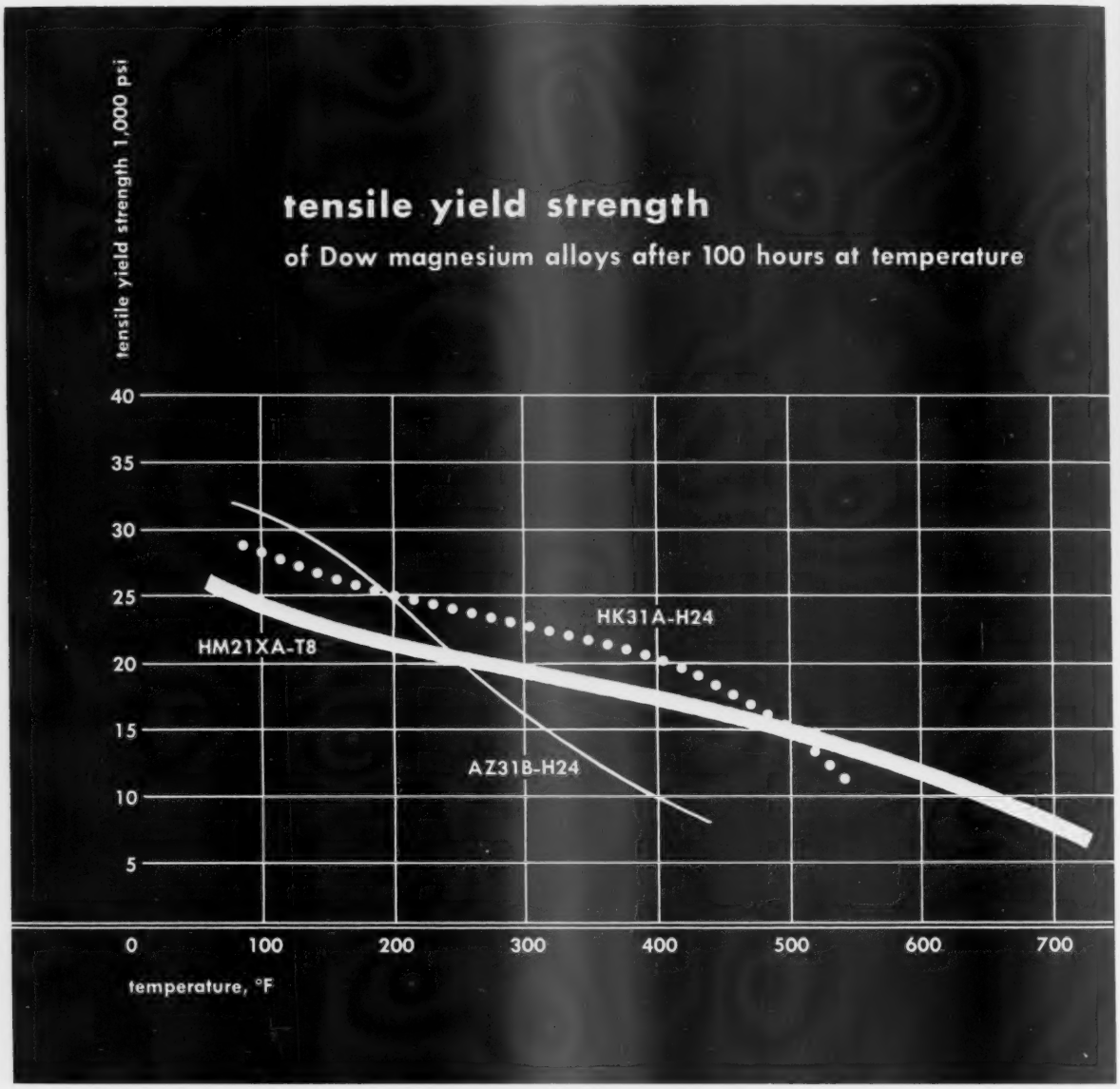


Thin sheets of heat-resistant stainless steel on the wings and tail of an experimental rocket plane helped it to safely set the newest world's speed record—1,900 m.p.h.



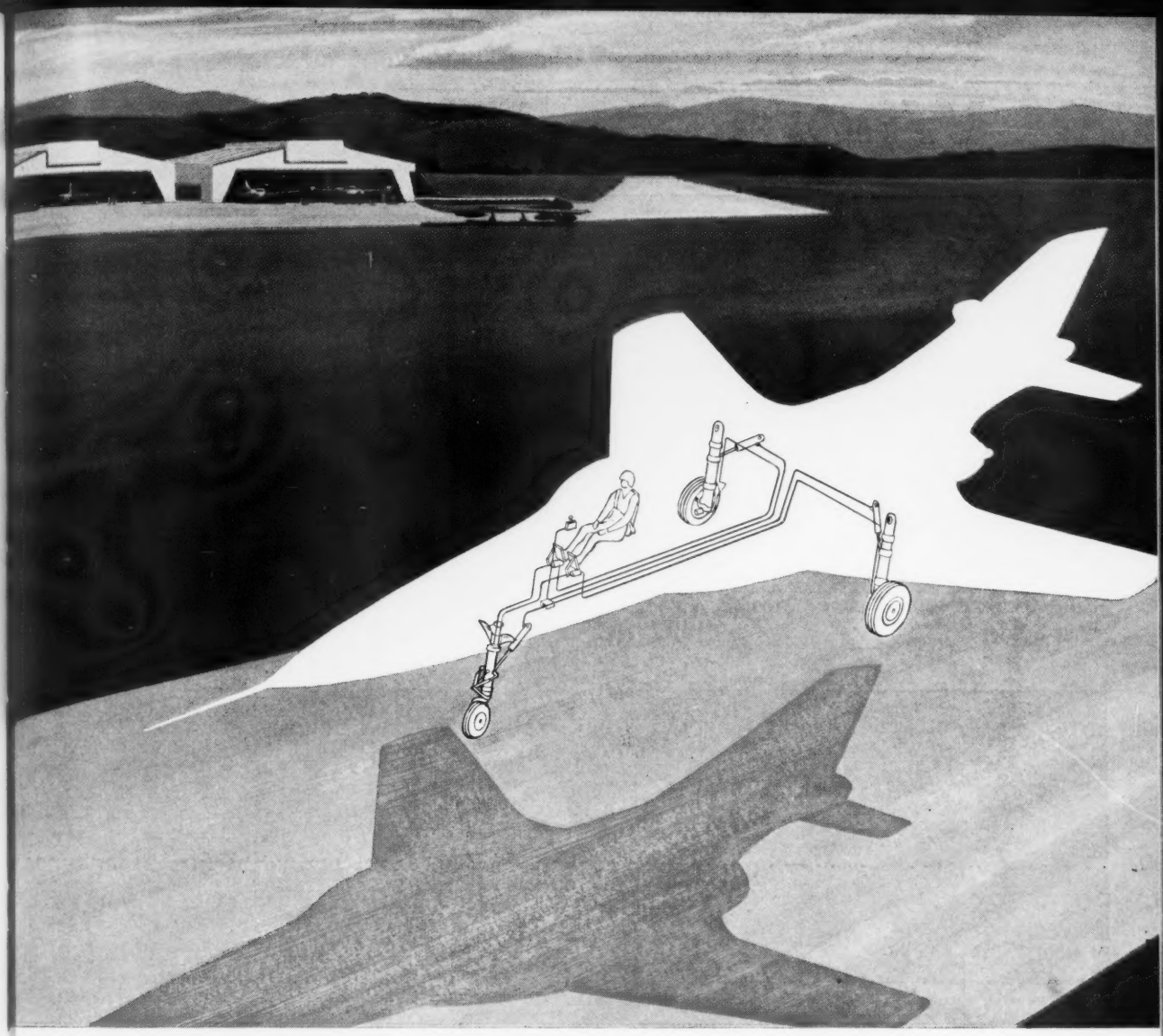
New magnesium alloy holds properties for 100 hours up to 700°F.

Dow Magnesium HM21XA-T8 alloy extends further the range of conditions under which light metals can be used in aircraft design. Second in the series of sheet alloys designed specifically for elevated temperature applications, it supplements the excellent characteristics of HK31A alloy.

HM21XA-T8 retains its properties at temperature during long periods of time. Even one hundred hours at 700°F. results in relatively little change in tensile yield, creep and elastic modulus.

Magnesium lightness is combined with strength at elevated temperature in HM21XA-T8, offering new ways to save weight or gain increased rigidity in the design of missiles and aircraft. This alloy is supplied in the -T8 temper and can be formed in this temper without the need for further heat treatment after fabricating. Samples of HM21XA-T8 along with detailed information are available. Contact your nearest Dow Sales Office or write to THE DOW CHEMICAL COMPANY, Midland, Michigan, Department MA 1400C.

YOU CAN DEPEND ON DOW



FROM TOUCHDOWN TO TAKE-OFF

WITH A COMPLETE BENDIX SYSTEM FOR LANDING GEAR

During ground contact, between touchdown and take-off, the safety of the plane and crew depends upon the unfailing teamwork of everything that makes up the landing gear system.

Retractor actuation, control valves, nose wheel steering, power braking, as well as wheels, brakes and shock-absorbing struts—even tires—these are the things that make up the complete landing gear system. And it is vital that all components function together with split-second accuracy and efficiency.

That is why Bendix specializes in complete and integrated landing gear systems. For, components that have been designed and engineered to work together give better and more dependable performance than any arbitrarily assembled system. The components of a Bendix landing gear system are engineered as a matched set, then tested and tuned to work together like a trained crew.

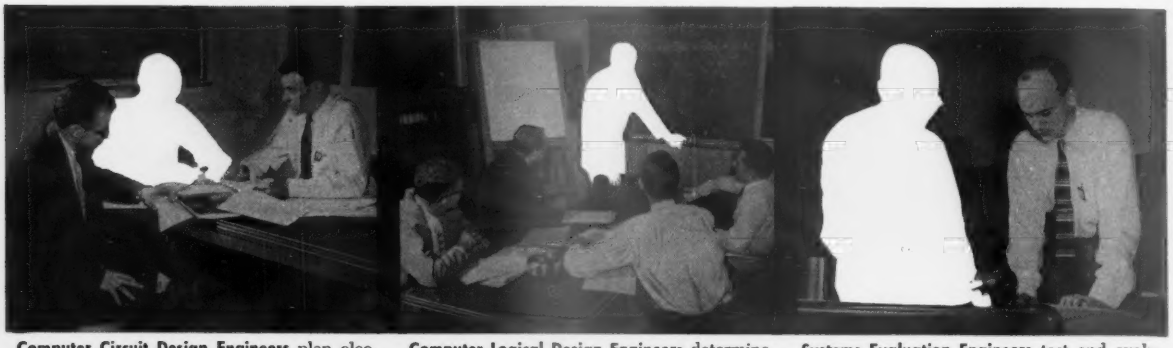
And there is a further important advantage in having one source completely responsible for production and over-all operation on the airplane.

So, when it comes to gear for landing, think and plan in terms of a complete landing gear system. Then we suggest you think of Bendix and Bendix Products Division at South Bend, Ind.

Bendix PRODUCTS DIVISION **South Bend,** IND.

Bendix
AVIATION CORPORATION

Where do you belong in



Computer Circuit Design Engineers plan electronic circuitry for advanced airborne analog and digital computers . . . design linear and pulse circuits employing transistors, tubes, magnetic devices. Opportunities also exist in airborne power supply design, or to develop new techniques for marginally checking computer performance. *Do you belong on this team?*

Computer Logical Design Engineers determine the systems outline of a computer and its inter-connection with external equipment. Close liaison is maintained with mathematical support, circuit design, packaging and test engineers. Computer speed, memory size, configuration and arithmetic structure are tailored to requirements of weapons systems. *Do you belong on this team?*

Systems Evaluation Engineers test and evaluate electronic analog and transistorized digital computer systems design for aircraft; evaluate new systems and improvements to insure compliance with specifications and Air Force requirements. Other assignments: tie-in testing of peripheral equipment, liaison with design, development and field engineering. *Do you belong on this team?*

Harry Branning (center): B.S.E.E. 1950, Syracuse. Design Engineer in circuit design, 1951; October, 1954, promoted to Associate Engineer; April, 1956, promoted to Staff Engineer, Systems Planning. In June, 1956, appointed Project Engineer and Manager of the 110 Computer Circuit Design Department; discussing the performance and packaging details of a transistorized read amplifier.

William Dunn (standing): M.E. 1950, M.S.E.E. 1952, Stevens Institute. Technical Engineer, 1955; April, 1956, promoted to Associate Engineer; August, 1956, transferred to Development Engineering in charge of Logical Design for digital computers in advanced weapons systems; here discussing Boolean Algebra method of optimizing the logical design of an airborne digital computer.

Eli Wood (left): B.S.E.E. 1950, Connecticut. IBM Customer Engineer, July, 1950; September, 1952, transferred to ACL Field Engineering. February, 1954, in charge of Field Engineering at Hunter AFB; May, 1955, Associate Engineer; appointed Project Engineer, Manager of Systems Evaluation in August, 1956; here investigating a problem in radar data presentation set evaluation testing.

The brief records of the men cited above indicate only a few of the exciting activities right now in IBM Military Products. This division, organized 18 months ago, has grown enormously. A small-company atmosphere prevails. Men work in small teams . . . individual contributions are instantly recognized. Promotions occur frequently.

As a member of IBM Military Products, you'll enjoy physical surroundings and equipment second to none. Educational programs at IBM expense lead to advanced degrees. Salaries and benefits are excellent. Stability is guaranteed by IBM's history of consistent achievement—underlined by the fact that the rate of turnover at IBM is only one-sixth the national average.

Throughout the length and breadth of the United States IBM has built modern plants and laboratories. This map points out the various locations where you might live as an IBM em-

DATA PROCESSING
ELECTRIC TYPEWRITERS
TIME EQUIPMENT
MILITARY PRODUCTS

IBM MILITARY PRODUCTS

IBM Military Products?

Systems Engineers oversee the engineering support provided by the Systems Coordination and Specification Group to the factory on the AN/ASB-4 Bombing-Navigational System. Air Force requirements are analyzed and the resulting engineering changes evaluated to determine effect on system performance and accuracy. Mathematical error analyses are run. *Do you belong on this team?*

Systems Analysts anticipate performance and recommend design criteria before and during development of equipment. Later, they compare dynamic performance accuracy and reliability characteristics with what has been anticipated. Other assignments include Digital Computer Systems Engineering, Input-Output and Analog-Digital Conversion Engineering. *Do you belong on this team?*

Quentin Marble (left): B.S.M.E. 1951, Syracuse. Joined IBM in 1951; promoted to Design Engineer in 1952; May, 1955, promoted to Associate Engineer, and then to Project Engineer, Manager of the Systems Coordination and Specification Group, Production Engineering Department, in February, 1956; shown here describing a unique cooling design to a new employee in his group.

Monroe Dickinson (left): B.S.E.E. 1952, W.P.I.; M.S.E.E. 1954, M.I.T. Technical Engineer in analog and alternate computer techniques for weapons systems, 1952; Associate Engineer responsible for systems design and analysis, 1954; December, 1955, Staff Engineer, responsible for research planning; here reviewing set-up on laboratory analog computer of a sampled data control problem.

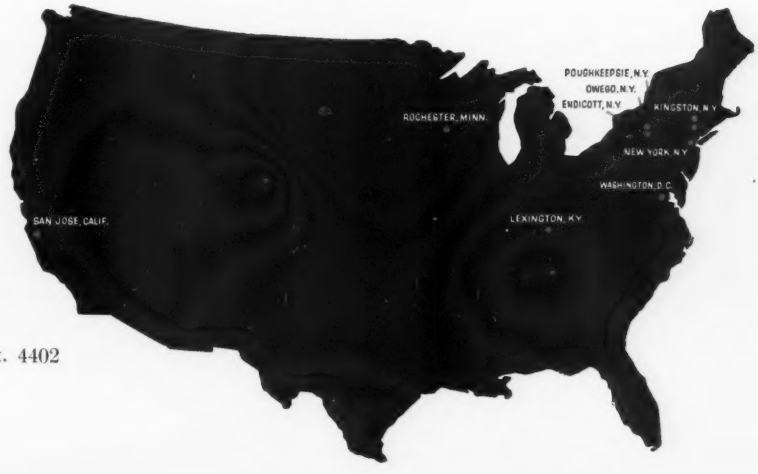
Exceptional career opportunities are now open in IBM Military Products for E.E.'s, M.E.'s, physicists, and mathematicians, in the following fields:

SYSTEMS PLANNING AND ANALYSIS
DIGITAL AND ANALOG SYSTEMS
INERTIAL GUIDANCE
SERVO-MECHANISMS
ELECTRONICS
MECHANICAL DESIGN
ELECTRONIC PACKAGING
PROGRAMMING
FIELD ENGINEERING
RELIABILITY
COMPONENTS
PHYSICS
MATHEMATICS
HUMAN ENGINEERING
INSTALLATION
CIRCUIT DEVELOPMENT
POWER SUPPLIES
TRANSISTORS
HEAT TRANSFER
OPTICS
TEST EQUIPMENT
COST ESTIMATING
TECHNICAL PUBLICATIONS

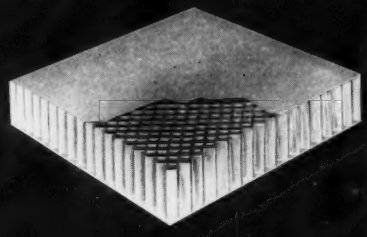
ployee. IBM Military Products include the Airborne Computer Laboratories located in Owego, N. Y., and the Project SAGE installations directed from Kingston, New York.

Here is a real ground-floor opportunity that you can't afford to overlook. Without exaggeration, your potential in this dynamic young field of electronic computers is virtually unlimited. Get all the facts. Write, outlining your background and interests to:

R. A. Whitehorne
Manager of Engineering Recruitment, Dept. 4402
International Business Machines Corp.
590 Madison Ave., New York 22, N. Y.



NEW STRUCTURAL CONCEPTS FOR MODERN FLIGHT



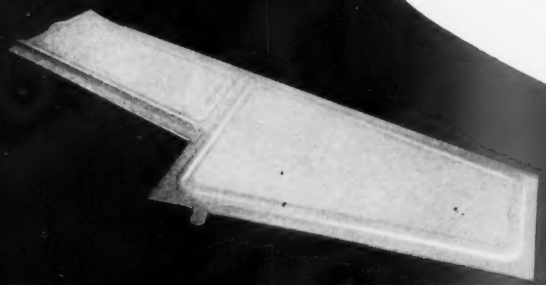
high temperature brazed stainless steel honeycomb

SANDWICH PANEL STRUCTURE

developed by Rohr, ranges in thickness from one-eighth of an inch to five inches and is used for straight, tapered, curved and compound contoured panels for wings, control surfaces and various similar applications. Strength values: edge compression 166,500 psi; simple beam, 10-inch span, 166,500 psi; short beam, two-inch span, 600 psi; F tu face 170,000 psi.

HIGH STRENGTH WELDMENTS

produced by Rohr meet high strength weight ratio requirements for modern airplanes. Rohr has developed special techniques for hot forming of detail parts and for heat treatment. Design of the weldments is an important factor in successful production, which is why Rohr supplies all production design of the units.



METAL BONDED STRUCTURE

comprises face skins, stiffening members and honeycomb core, and is being produced by Rohr for wing, power plant and empennage fairings, skin sections, trim tabs, deicer provisions and many other similar applications to take the place of rivets and bolts. Many such structures involve the joining of dissimilar metals to achieve weight reduction, giving wider latitude in aircraft design.

Excellent career openings for engineers and skilled technicians

ROHR
AIRCRAFT CORPORATION

WORLD'S LARGEST PRODUCER OF READY-TO-INSTALL POWER PACKAGES FOR AIRPLANES

PLANTS IN CHULA VISTA AND RIVERSIDE, CALIFORNIA; WINDER, GEORGIA; AUBURN, WASHINGTON

NEW

Militarized Variac

20 Ampere

for 350 to 1200 cycle service

Manufactured to conform with rigid military specifications for shock, vibration, salt spray and tropicalization, including:

- High and low temperature lubrication (mil grease)
- Iridite treated aluminum parts
- Fungicidal treatment of all phenolic parts
- NEW, nickel-plated brush holder

Operates at any frequency between 350 and 1200 cycles.

New brush assembly removable radially for easier accessibility; has low sprung weight, coil springs, pigtails to carry current, improved heat transfer to radiator, limited travel.

As in other "M" high-frequency VARIACS, the M20 Series features stamped base and radiator for improved shock resistance and protection; improved heat transfer between coil and base for cooler operation.

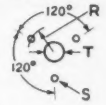
Type M20
VARIAC

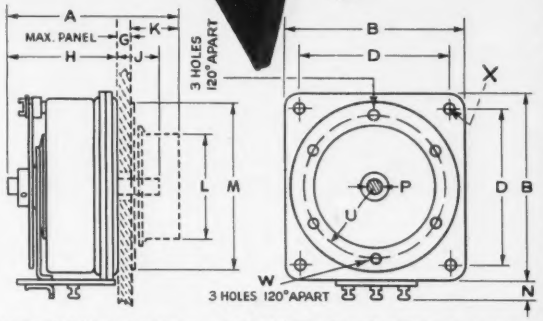
Specifications type M20 Variac

Input Voltage:	**115 volts, 350 to 1200 cycles**
Load Rating (kva)	**3.0**
Output Voltage	0–115 or 0–135
Rated Current (amp)	20.0
Maximum Current (amp)*	26.0
No-Load Loss at 400 c. (watts)	27
Dial Calibration	0–115 and 0–135
Angle of Rotation (deg)	319
No. Turns on Winding	169
D-C Resistance, 20°C.	0.153 ohm
Driving Torque (oz.-in.)	30–60
Replacement Brushes	VBT-8 $2.00
Net Weight (lbs.)	13
Code Word	CAVIL
Price	$48.00
Ball Bearings (surcharge)	8.00 (add "BB" to Type No.)

*For 0 to line-voltage output connection only

DIAL DRILLING DIMENSIONS FOR PANEL MOUNTING





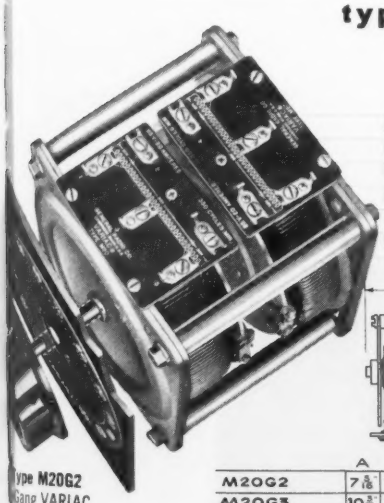
	A	B	D	G	H	J	K	L	M	N	P	R	S	T	U	W	X
M20	5 11/16	7 1/2"	6 1/4"	1/2"	3 3/16"	1 1/2"	1 5/8"	4 1/2"	7"	17/32"	1/2"	5/8"	#31	5/8"	3"	1/4-28	3/8

type M20 Variac® Assemblies

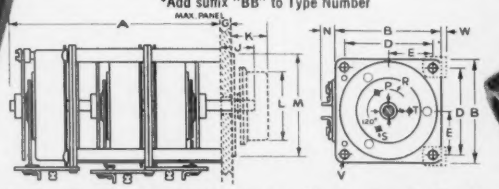
for 350 to 1200-Cycle Service

	2-Gang M20G2 Uncased	3-Gang M20G3 Uncased
Dial Calibration	0-10	0-10
Driving Torque (oz.-in.)	60-120	90-180
Net Weight (lbs.)	26½	38½
Code Word	CAVILGANDU	CAVILGANTY
Price	$107.00	$155.00
Ball Bearings (surcharge)*	$ 10.00	$ 12.00

*Add suffix "BB" to Type Number



Type M20G2
2-Gang VARIAC



Type M20G3
3-Gang VARIAC

	A	B	D	E	G	J	K	L	M	N	P	R	S	T	V	W
M20G2	7 5/16"	7 1/2"	6 1/4"	3 1/8"	1/2"	1 1/2"	1 5/8"	4 1/2"	7"	17/32"	1/2"	5/8"	#31	5/8"	1/4-28	7/32"
M20G3	10 3/4"	7 1/2"	6 1/4"	3 1/8"	1/2"	1 1/2"	1 5/8"	4 1/2"	7"	17/32"	1/2"	5/8"	#31	5/8"	1/4-28	7/32"

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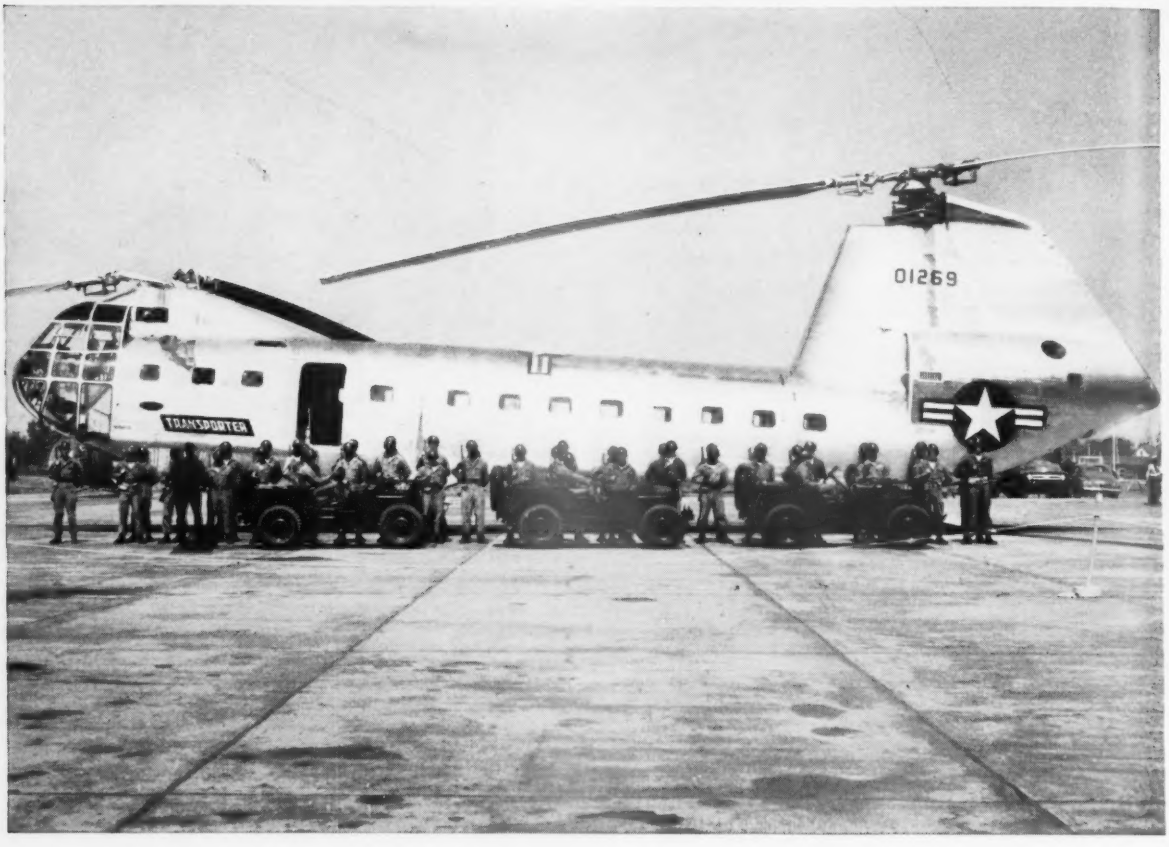
8055 13th St., Silver Spring, Md. **WASHINGTON, D. C.** 1000 N. Seward St. **LOS ANGELES 38**



World's largest 'copter...

Rotor hubs of 4340 steel support 16-ton craft carrying 40-man, combat-equipped platoon

Rotor hubs for Vertol Aircraft Corporation's giant whirlybird posed a twofold problem:

First, they had to be strong . . . strong enough to lift over 16 tons including her payload. They needed high shock and fatigue-resistance, too. And they had to be *light*.

Second, because of their complexity, the hubs had to be brought up to uniform strength by heat-treatment prior to machining. Thus a steel was required that would respond to such heat treatment in heavy sections and provide safe strength characteristics in light sections.

4340 does the job on both counts

4340 chrome-nickel-moly steel provides 150,000/170,000 psi tensile strength in heavy sections. It also provides desired fatigue and shock resistance.

4340 solves the rotor hubs production problem, too. Even after machining away 75% of the metal, after heat treatment the remaining section has the desired high strength.

Vertol specifies 4340 steel for other rotor components

4340 also gives Vertol desired properties in vertical and horizontal link pins...rotor shafts...and planetary carriers. In other parts of the YH-16A, Vertol uses carburizing type nickel steels for strength and wear resistance, austenitic types to withstand heat and corrosion.

If you have a difficult design problem, chances are one of several grades of nickel alloy steels is the answer for you, too. Send us details of your problem and we'll be happy to help you make the right selection.

INCO TRADE MARK **THE INTERNATIONAL NICKEL COMPANY, INC.** 67 Wall Street New York 5, N.Y.

ANOTHER FIRST BY PSC APPLIED RESEARCH LTD.

The World's most efficient Ice Detection System . . .

You are looking at the most efficient ice detection system yet developed — the Type T260 dual probe detector. Here is a 1¾-pound, sealed package unit that either warns the pilot of icing conditions long before he can see ice forming, or automatically controls his ice shedding system — depending on the application of the 28 volt output pulse.

Engineered and manufactured by PSC Applied Research Limited, under license from the National Research Council of Canada, the detection and reference probes and associated pressure switch are contained in a sealed unit, eliminating inter-connecting pneumatic tubing and reducing electrical cable requirements. Operationally proven by the RCAF and now standard equipment on the Avro CF-100 and its Orenda jet engines, the ice detection system is now available to private and commercial aircraft operators. Write us for literature and quotations.

Specifications:

Size — 3⅛" x 3⅛" x 5²¹⁄₃₂"
Probes — 3" long, 5⁄16" diameter
Weight — 1¾ pounds
Power — 28 volts, 15 amps. Intermittent

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Beyond the Speed of Sound in a Split Second

Aerophysics HTV Rocket

probes the temperatures of Hypersonic Flight

Only speeds many times that of sound can supply the answers to today's vital questions about the "thermal thicket" where ordinary aircraft metals blister and disintegrate and ordinary windshields turn to liquid glass. These are the speeds of the future – not only for missiles, but for military and civil aircraft as well.

Curtiss-Wright's subsidiary, Aerophysics Development Corporation – working with the Wright Air Development Center of the U.S.A.F. Air Research and Development Command – has provided an ideal tool for this research in the just-announced HTV Hypersonic Test Vehicle. Reaching several times the speed of sound in only two seconds, this two-stage, ten-foot missile is topped with a two-foot nose cone where data on heat and air pressure are recorded.

The HTV is only the first in a family of such rockets on which Curtiss-Wright task scientists are at work. It is a dramatic example of Curtiss-Wright's developmental leadership in every advanced category of airpower.

AEROPHYSICS DEVELOPMENT CORPORATION
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Message from Melbourne

A recent short-wave broadcast from Melbourne, Australia . . . received in Syracuse, N. Y. (over 10,000 air miles) **with no perceptible flutter or fading** . . . is further proof that General Electric's new radio technique . . . Synchronous Amplitude Modulation*. . . is the solution to the problems of long-range radio operations. Its concept and operation are uniquely simple . . . SAM* is compatible with all present forms of radio equipment . . . its operators need no further specialized training . . . yet it preserves complex wave forms even while handling the Doppler effect. Its suppressed-carrier, double-sideband transmission and synchronous reception promise significant savings in weight and cost. Of paramount importance is SAM's* resistance to jamming and interference. Here again, is a vivid example of LMEE's invaluable contribution to progress... in furthering new uses for electronics.

For the very latest information on SAM* . . . write Section E

LMEE

Aviation Electronics Products Include:

WEAPONS CONTROL RADAR • SEARCH RADAR • INDICATORS AND DISPLAY • COUNTERMEASURES • NAVIGATION
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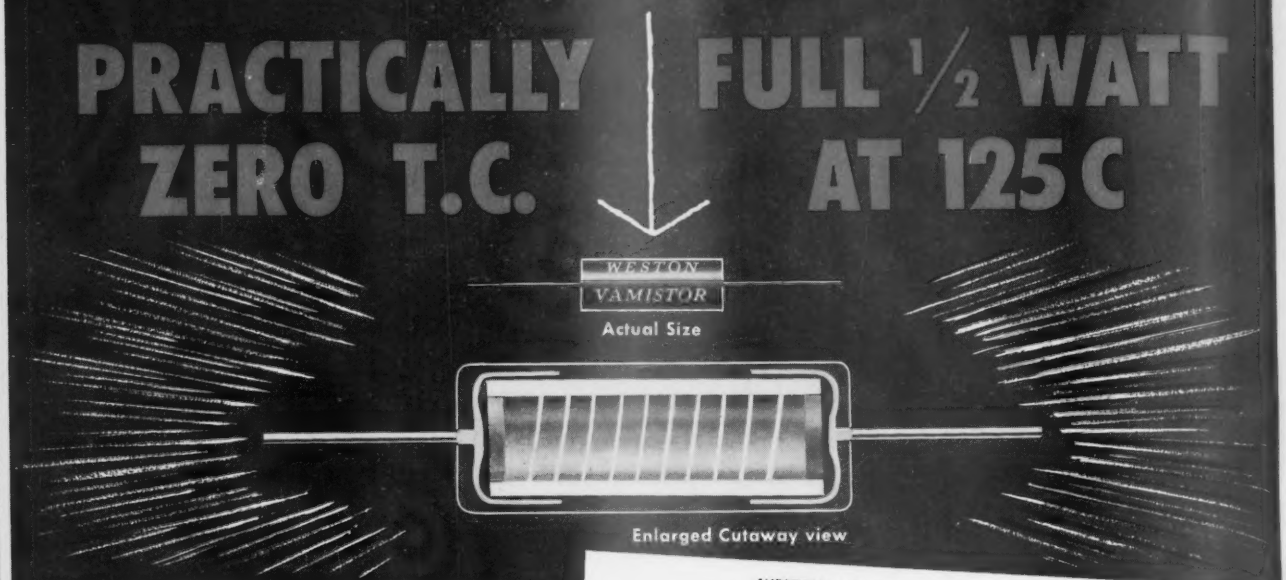
FOR HIGHEST STABILITY...

WESTON precision in a metal film resistor...

PRACTICALLY ZERO T.C.

FULL ½ WATT AT 125 C



Actual Size

Enlarged Cutaway view

The Weston VAMISTOR offers you many advantages over wire wound or conventional film resistors, in critical applications. It is a sealed, metal-film resistor that provides greater stability than all previous types. Following are a few of its outstanding characteristics:

- Stable under temperature, moisture and load life
- Stable under vibration, acceleration
- Non-inductive
- Noise free
- Excellent HF performance

As shown on table at right, VAMISTORS meet or surpass MIL specifications. They are now available in the following types:

	INITIAL TOLERANCE	TEMP. COEFF.
Model 9851 — ½ watt at 85C	1% or .5%	± 50 or ± 25 ppm
Model 9852 — ½ watt at 125C	1% or .5%	± 50 or ± 25 ppm
Model 9853 — 1 watt at 70C	1% or .5%	± 50 or ± 25 ppm

all models available in resistance values from 1000 to 100,000 ohms

For complete information on VAMISTORS, return the coupon today.

WESTON VAMISTOR PERFORMANCE DATA
COMPARED WITH SPECIFICATIONS FOR OTHER PRECISION TYPE RESISTORS

Characteristic	Vamistor production units	MIL-R-19074A (ships) Style RI-94	Wirewound MIL-R-93A Style RB-52 Char. A	Film MIL-R-10509B Style RN-70 Char. A
Short Time Overload 2.5 Times—10 min	Average + .01% Low .00% High − .06%	.5% max.	.5% max.	.75% max.*
Load Life 1000 hr—85 C	Average + .15% Low + .10% High + .20%	.5% max.	.5% max.	1.0% max.**
Low Temperature −65 C—24 hours	Average .00% Low .00% High + .02%	.5% max.	(no test)	1.0% max.
Moisture Resistance MIL-STD-202, Method 106	Average + .23% Low + .15% High + .36%	.5% max.	1.0% max.	3.0% max.
Salt Water Immersion 0 to 85 C—5 cycles	Average − .04% Low + .02% High − .10%	.5% max.	.5% max.***	(no test)
Temperature Cycle −55 to 85 C—5 cycles	Average + .04% Low + .02% High + .07%	.2% max.	.2% max.	1.0% max.
Insulation Resistance 100 v d-c	Greater than 10,000 megohms	100 megohms min.	50 megohms min.	10,000 megohms min.
Dielectric Strength 900 v rms—1 minute	Below measurable value—all samples	.05% max.	.05% max.	.5% max.
Terminal Strength		.5% max.	(no limit)	.5% max.
Effect of Solder		.5% max.	(no test)	.5% max.

*MIL-R-10509B test 2.5 times—5 seconds **MIL-R-10509B test at 70 C ambient
***MIL-R-93A test not cycled. 25 C—24 hours

Weston Electrical Instrument Corp.
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Rush me full particulars on WESTON precision metal film resistors.

Name _____

Company _____

Address _____

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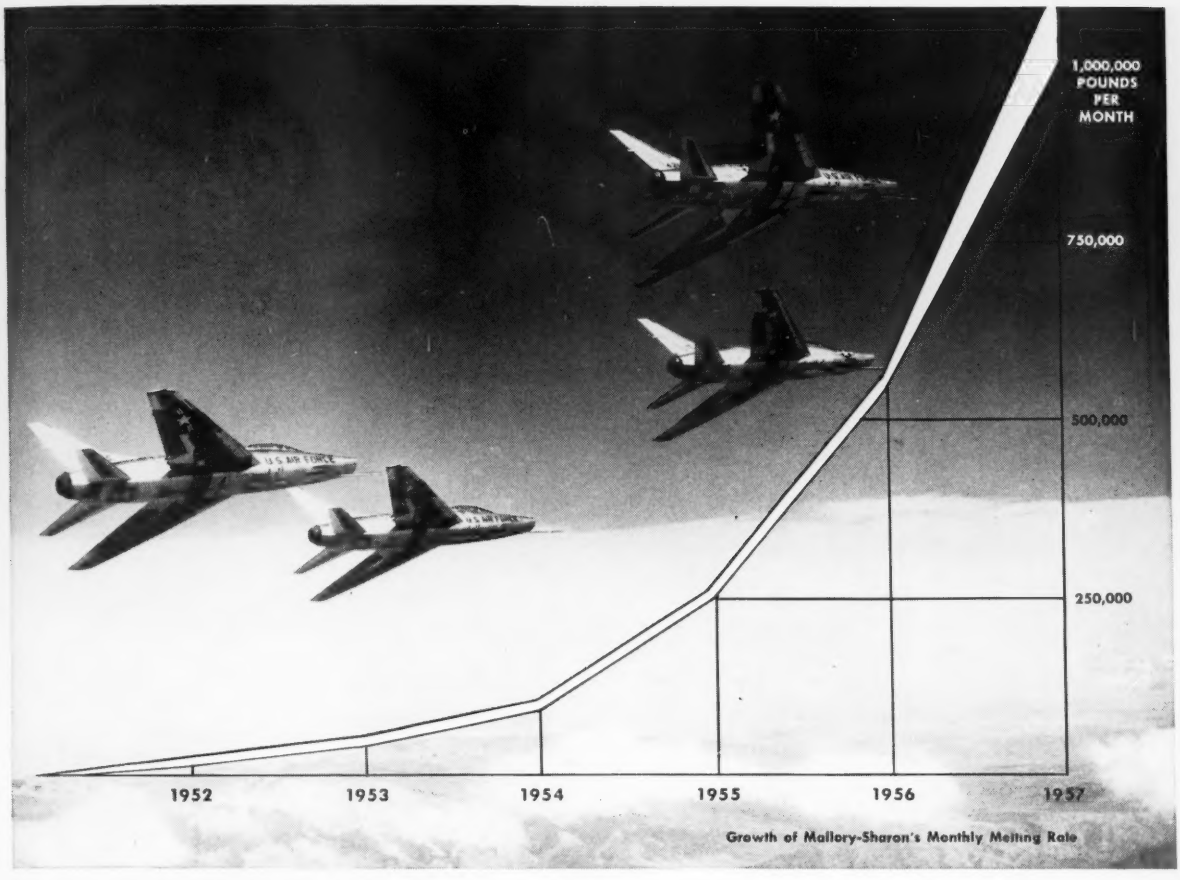
WESTON VAMISTORS

precision metal film resistors

A WESTRON UNIT

Progress with **TITANIUM**



TITANIUM IN 1957:

Mallory-Sharon nears 1,000,000 pound-per-month capacity, dramatically improves quality, introduces new alloys

• Titanium continues to be a wonder metal in its growth.

This year Mallory-Sharon, a leader in titanium mill products, will produce more than the entire titanium industry in 1955. A major plant expansion now nearing completion will boost Mallory-Sharon's melting capacity to one million pounds per month.

And this is vastly better titanium than that of two years ago, since properties of the metal are now under much better control. We certify titanium mechanical properties within definite limits. We guarantee very low carbon content to assure the best machineability. As a result major titanium fabricators have drastically cut scrap loss, and costs.

New developments will continue to expand titanium's market. Weldable alloys, commercially introduced by Mallory-Sharon, have been proved in service. New sheet alloys, readily weldable and heat treatable to very high strengths, are in trial production.

Titanium is vital to our air superiority. And new applications of this strong, light, corrosion-resistant metal are being found each day in industry. Let Mallory-Sharon, technical leader in titanium, help you design ahead with this new metal. Write for information and application assistance.

MALLORY Ti SHARON

MALLORY-SHARON TITANIUM CORPORATION · NILES, OHIO

Producers of titanium and titanium alloy sheet, strip, plate, rod, bar, billets

IMPORTANT ACHIEVEMENTS AT JPL

The Jet Propulsion Laboratory is a stable research and development center located north of Pasadena in the foothills of the San Gabriel mountains. Covering an 80 acre area and employing 1600 people, it is close to attractive residential areas.

The Laboratory is staffed by the California Institute of Technology and develops its many projects in basic research under contract with the U.S. Government.

Opportunities open to qualified engineers of U.S. citizenship. Inquiries now invited.

Development of the Sergeant

Announced as a successor to the Corporal is another highly accurate surface-to-surface ballistic missile named "The Sergeant." This weapon will continue the United States Army's advance in the development of mobile firepower.

The latest techniques in guidance, airframe design and rocket propulsion are being applied to the development of this rugged weapon which is capable of operating in any area.

The Jet Propulsion Laboratory, designer of this new missile, has the same prime technical responsibility to provide the development of the complete Sergeant system as it had for the Corporal weapon system.

In addition to weapon development the "Lab" carries on supporting research in all areas related to guided missile work. These supporting research and weapon development activities complement and extend each other to produce superior end results.

This fact, coupled with ideal facilities and working conditions at JPL, is a prime attraction for scientists and engineers of unusual ability because of their close integration with such vital programs. At the same time, other varied and interesting activities in weapon development are providing new challenges and openings for qualified people.

JOB OPPORTUNITIES ARE NOW AVAILABLE

jpl

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JET PROPULSION LABORATORY

A DIVISION OF CALIFORNIA INSTITUTE OF TECHNOLOGY
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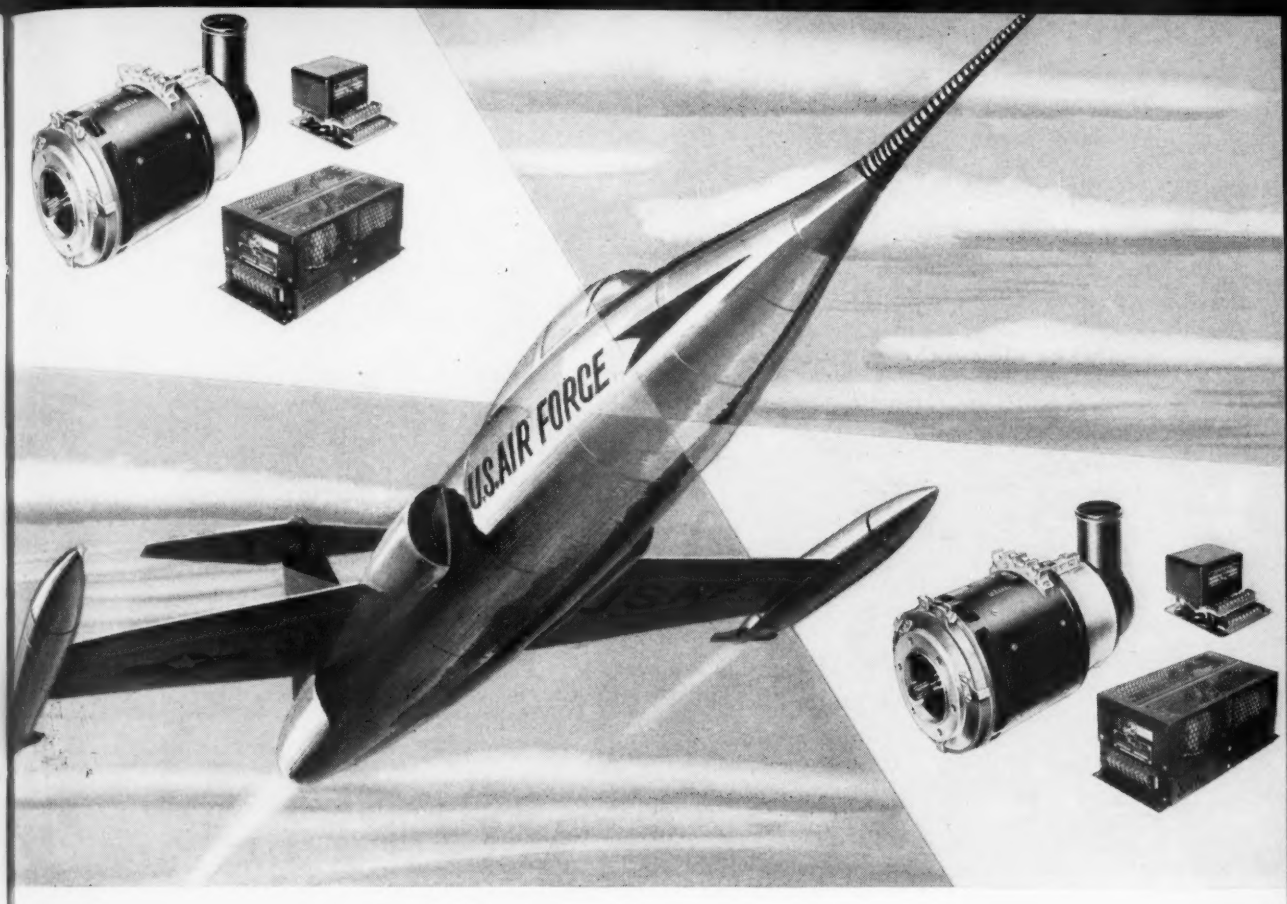


BENDIX DUAL GENERATOR SYSTEM HELPS MAKE LOCKHEED F-104 WORLD'S FASTEST FIGHTER

Jet-Age Advantages Offered By Bendix System:

High-temperature AC generator: 20 KVA, 400-cycle, 3-phase unit operating in 4800 to 7200 rpm range. Generates 120/208 volts. Exceeds Class "C" military requirements. Advanced design, including oversized exciter, permits taking very heavy intermittent loads "in stride". Driven directly by engine for increased reliability, less maintenance, over-all weight savings.

Magnetic amplifier voltage regulator: Completely static design eliminates all moving parts. Silicon rectifiers eliminate operating difficulties ordinarily encountered at high temperatures. Special vibration-resistant construction eliminates need for vibration isolaters and thus conserves critical space.

Automatic control panel: Hermetically sealed, environmental-free unit provides complete system control. Pilot operates entire automatic system from single toggle switch.

Supplying electrical power to the Air Force's top-performing Starfighter is a job calling for all-out performance and reliability.

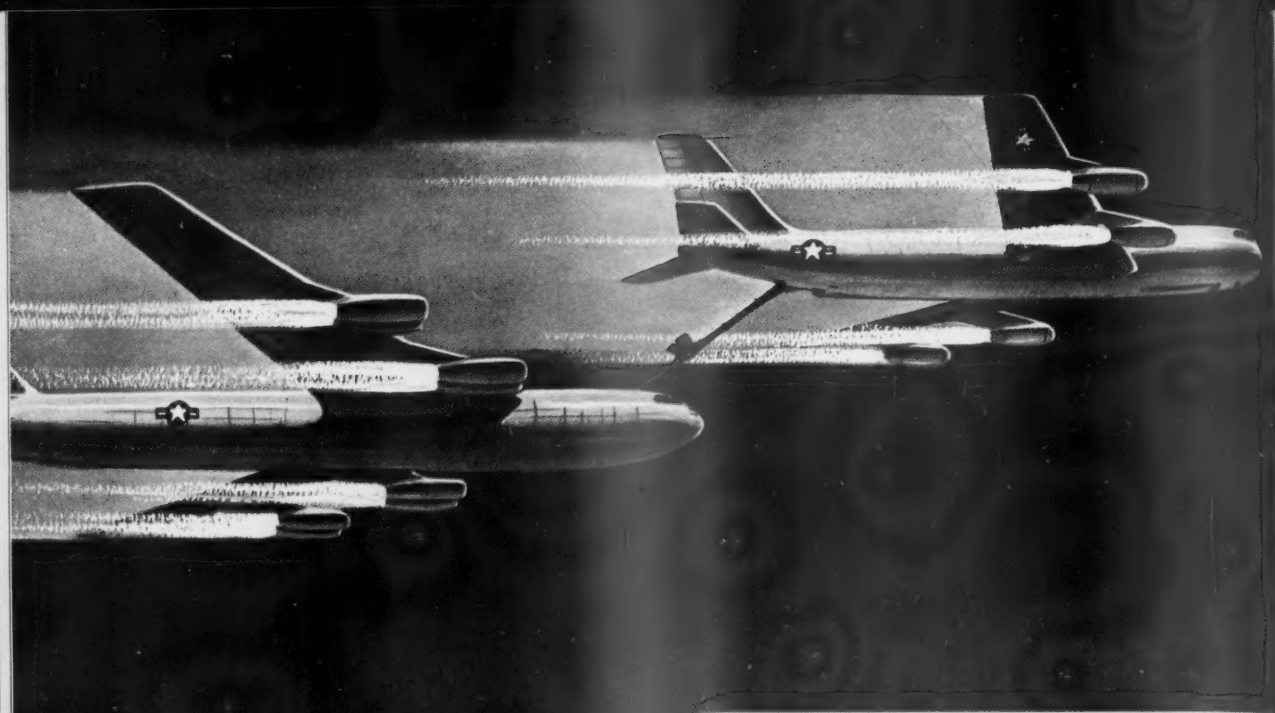
The Bendix AC generator setup aboard the F-104 is a *dual* system, with either system able to handle the entire electrical load alone, if necessary. Developed by Bendix Red Bank Division, the system has many advanced features and advantages (see adjoining column) that enable it to answer the many difficult problems arising from the complex needs of an airplane that can climb with the speed of sound.

Our experience, manpower and facilities have produced *many* "firsts" and "bests" in the aircraft generator system field. Perhaps we can come up with a better answer to your needs, too. RED BANK DIVISION, BENDIX AVIATION CORPORATION, EATONTOWN, NEW JERSEY.

West Coast Office: 117 E. Providencia, Burbank, Calif.
Export Sales and Service: Bendix International Division, 205 E. 42nd St., New York 17, N. Y.
Canadian Affiliate: Aviation Electric Ltd., P. O. Box 6102, Montreal, Quebec.

Red Bank Division

Bendix
AVIATION CORPORATION



HIGH LEVEL DELIVERY

You're looking at a big forward step in American air power. The Boeing KC-135 jet tanker-transport shown refueling a B-52 goes *up* and *after* the supersonic bomber to deliver a fuel load. No longer will the B-52 have to *come down* and *slow down* to get its fuel. This means faster, safer, more efficient refueling and longer range operation for the B-52.

Foote Bros. has provided, and is providing for these aircraft, important Precision Assemblies for surface control mechanisms, as well as Precision Aircraft Quality Gears for the engines that power them.

We are proud of the confidence placed in us by the aviation industry, and prouder still of the performance of Foote Bros. components in these and other aircraft.

For design, development, and/or production of Precision Aircraft Engine Type Gearing, actuators and power transmission, come to Foote Bros. first. It will pay you dividends.

this trademark stands for the finest industrial gearing made

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Better Power Transmission Through Better Gears

FOOTE BROS. GEAR AND MACHINE CORPORATION

4545 South Western Boulevard, Chicago 9, Illinois

A Two extension coil springs hold assembly against shaft.

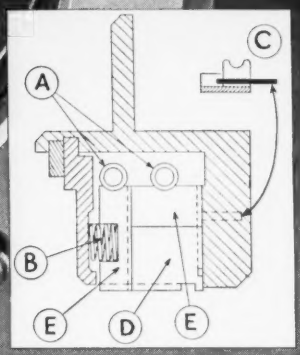
B Axial compression springs exert constant positive pressure toward the sealing face.

C Key and pin assemblies lock carbon segments against rotation.

KOPPERS CIRCUMFERENTIAL SEAL

PROVIDES UP TO 2000 hrs. OF PERFORMANCE

CAN USE LESS THAN 5 h.p.



D Flexible sealing segments permit seal to achieve same circularity as shaft.

E Straight-cut joints are covered and sealed by segmental cover ring and segmental back ring.

A number of finite joint gaps allow for ring wear.

Koppers Circumferential Seal is a segmented carbon seal ring with straight-cut joints. Its design can be modified to use step type joints or step seal joints. Primarily a gas seal, the Koppers Circumferential Seal will seal liquids if the geometry of the shaft mating faces is changed.

Koppers Circumferential Seals are one of a large variety of seals designed and manufactured by Koppers for every industrial use. Because of this complete line, Koppers can recommend, without bias, the seal best suited to your specific application. And Koppers continuous development and testing of new designs and new materials assure you of the most advanced, most efficient seals for your purpose. If you have a sealing problem, write to the KOPPERS COMPANY, INC., Metal Products Division, Piston Ring and Seal Department, 2202 Scott St., Baltimore 3, Maryland.

Engineered Products
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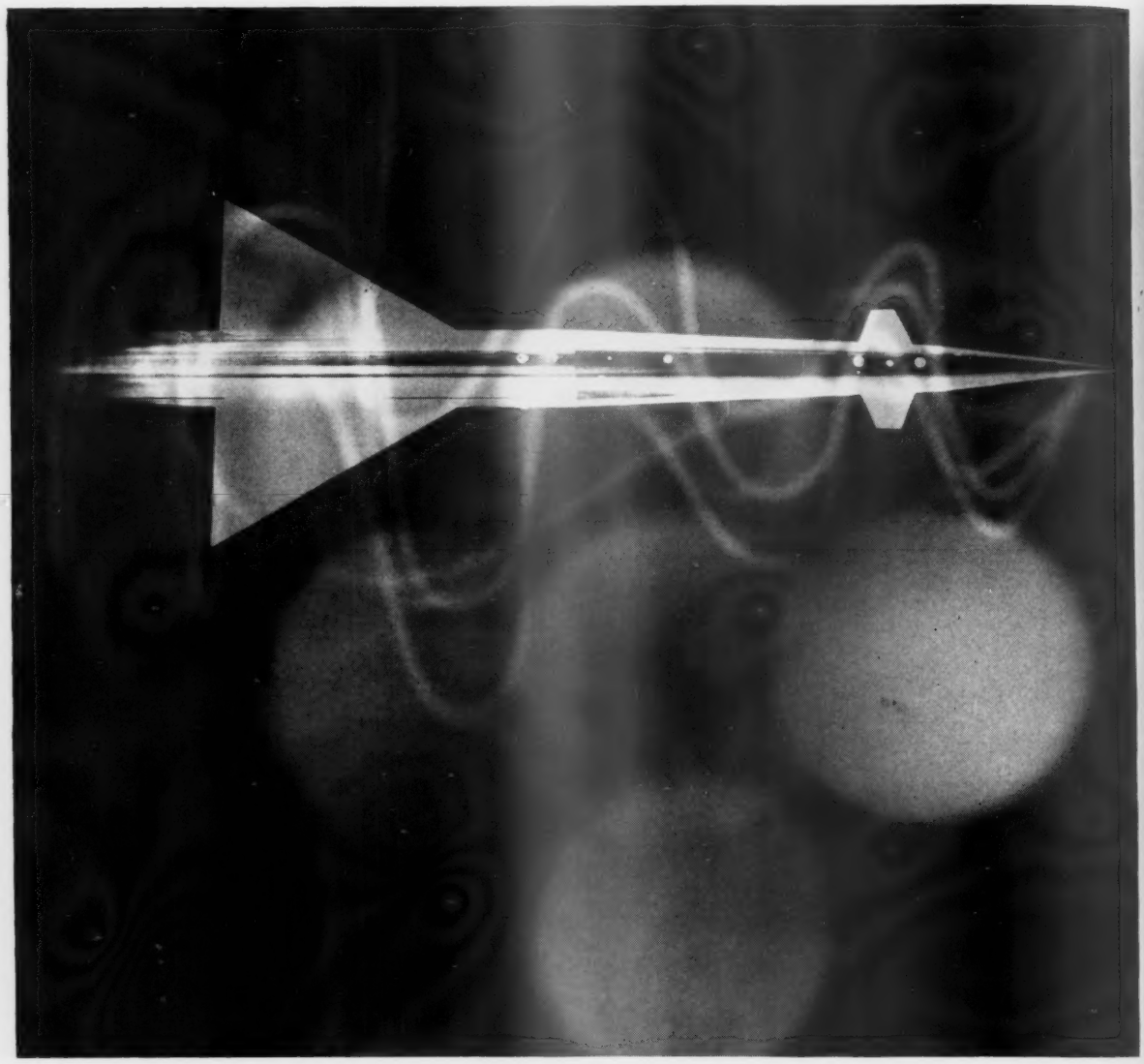
KOPPERS

MECHANICAL SHAFT SEALS



Portrait of a man's supersonic alter ego

The speeds and altitudes achieved by today's aircraft have placed them beyond a human pilot's physical resources. They fly faster than he can think, decide and react . . . exert forces beyond his own strength or that of old-time hydraulic systems.

The answer: electro-mechanical colleagues with the superhuman reflexes, sensitivity and strength to cope with the phenomena of supersonic flight.

At AUTONETICS, Automatic Pilots are being designed and produced that will control a vehicle during its mission, referenced by input signals from the Pilot, Autonavigation Equipment, and Fire Control Systems. These Autopilots are able to control a vehicle throughout an extreme flight regime more precisely and swiftly than the human pilot.

In addition AUTONETICS has developed an Automatic flare computer integrated with the Autopilot for fully automatic or semi-automatic landings in manned or unmanned vehicles. In the case of manned vehicles, flare signals are provided to the pilot through the ILS indicator. The flare computer thus adds all-weather capabilities to any vehicle by providing a controlled flight path to touchdown under the most adverse weather conditions.

AUTONETICS is a quality and quantity producer of flight control, autonavigation, armament control, computer and other complete control systems with significant implications for commerce and industry.

For more information—or for employment in this dynamic field—write: AUTONETICS, Dept. AER-71, 12214 Lakewood Blvd., Downey, California.

Autonetics

A DIVISION OF NORTH AMERICAN AVIATION, INC.

AUTOMATIC CONTROLS MAN HAS NEVER BUILT BEFORE

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What you can expect from Cooper Shelf Service is illustrated by this typical customer inquiry which found all items available for immediate shipment—additional quantities available within two weeks.

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AN 12C-43	325
AN 3DD-4A	34000
AN 8DD-35A	1300
AN 23-8A	45000
AN 30-50	450
AN 73-2	11500
AN 80-15	385
AN 73-A2	9700
AN 81-A47	210
AN 173-3A	6300
AN 182-41	570
AN 173C-5A	5200
AN 178C-47	420
AN 174DD-4A	1350
AN 177DDH-21	490
NAS 333-PA-3-45	64000
NAS 340-A25	275
NAS 428-3-6	14000
NAS 428-6-16	940
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NAS 464-16-45	340
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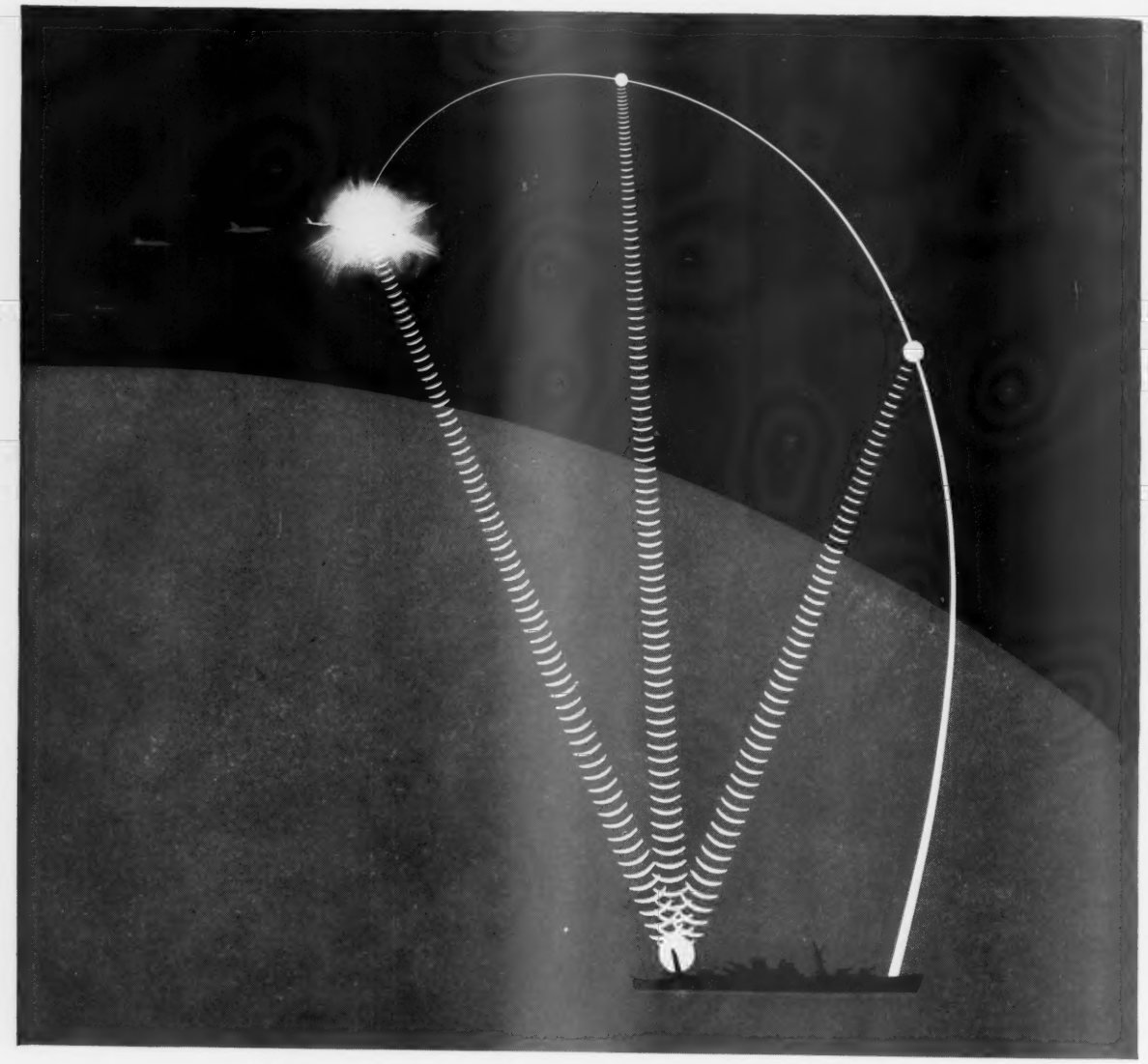

When you need to know the "score"...

AMF has experience you can use

● A supersonic missile, even though out of sight, is never "out of mind". The commander directing the attack must know how effectively the missile performed its mission of destruction. And intricate AMF feed-back equipment tells him—sending an automatic report-card from launching to final target "kill". ● Keeping tabs on the flight of a missile is but one of the hundreds of complex tasks AMF performs every day. The highly specialized yet widely diversified activities of some 35 engineering and production facilities provide AMF with a wealth of experience that covers nearly every field of industry. And it is immediately available to you. ● Call upon AMF with your problem. See for yourself why this all-around experience in answering the needs of government and industry alike has made AMF a "can do" company.

- *Armament & Ballistics*
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Another AMF Product
DEFENSE PRODUCTS

Defense Products Group
AMERICAN MACHINE & FOUNDRY COMPANY
1101 North Royal Street, Alexandria, Va.

Anything that can be postulated is possible, says science—including *timelessness.*

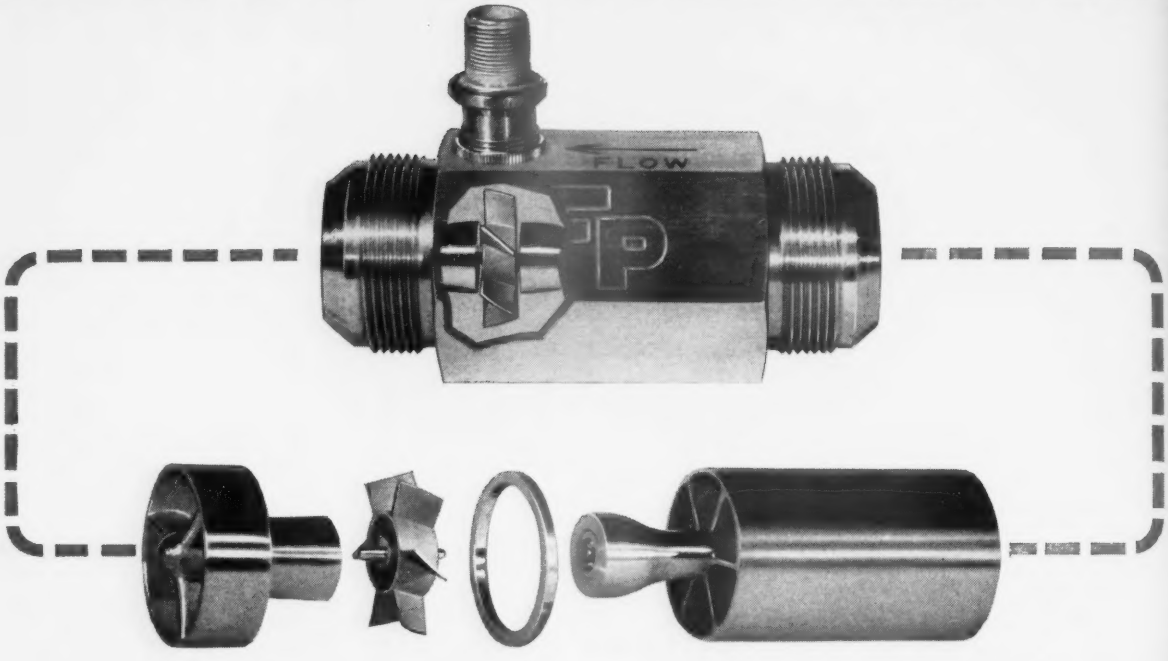
The latest table-talk among the rocket and missile men has to do with the physics (and metaphysics) of photon propulsion: thrust for a space vehicle derived by shooting incredibly concentrated beams of light (photons) from its tail. Result—speeds approaching that of light! Round trips to distant galaxies could thus be accomplished in a single generation of the crew. Meanwhile, however, the Earth would have passed through a billion years—possibly into cosmic oblivion!

The space-time ratio is increasingly a factor in the calculations of a brand new field of science known as astronautics...Work in this field at Martin is already at the threshold of tomorrow.

MARTIN

BALTIMORE·DENVER·ORLANDO

The big difference is inside the NEW F&P TURBINE METER



NOW AVAILABLE TO YOU is the new F&P Turbine Meter—made to the same high standards that has made Fischer & Porter a world leader in flow measurement know-how.

Also from F&P you can secure a complete line of electronic digital and analog readout instruments, associated data handling instrumentation and unsurpassed calibration facilities—making the application of F&P Turbine Meter practical—dependable and easy to integrate into systems operation.

Inherent precision accuracy.

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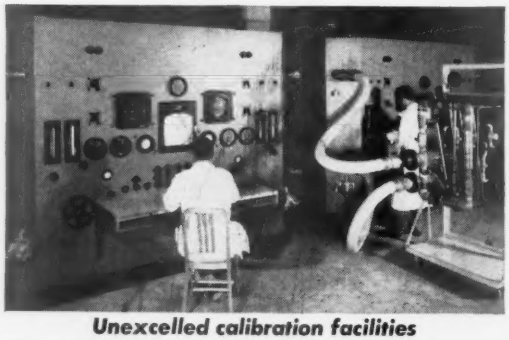
Write today for complete information on the F&P Turbine Meter. Test it in your own processes and you'll agree that here is a better, sturdier, less costly turbine meter than ever before available. Write to Fischer & Porter Co., 1927 County Line Road, Hatboro, Penna.



Unexcelled calibration facilities

The Colburn Memorial Flow Laboratory at Fischer & Porter, the finest and most modern of its kind in the world, provides the basic standards for flow measurement of all F&P flow meters.

FP FISCHER & PORTER CO. Hatboro, Pa.

COMPLETE PROCESS INSTRUMENTATION

LA1143

How Holley's Compressor Governors Help New Jets to Supersonic Speeds

"City-savers" Air Force men call them: the J-57-powered F-100, F-101, F-102 and Navy F8U, with level flight speeds faster than sound. And city-savers they could well be. Certainly their rapid approach to the fringe of Mach 2 heralds a new era in the progress of jet flight.

Sharing in the development of this new brood of supersonic fighters, Holley engineers, working closely with Pratt & Whitney Aircraft on the J-57 engine, designed the compressor bleed governor.

This new Holley compressor bleed governor is one more example of Holley's continuing leadership in the design, development and manufacture of superior engine control systems for both military and civilian use.

Leader in the design, development, and manufacture of aviation fuel metering devices.

HOLLEY Carburetor Co.

11955 E. Nine Mile Road — Van Dyke, Michigan

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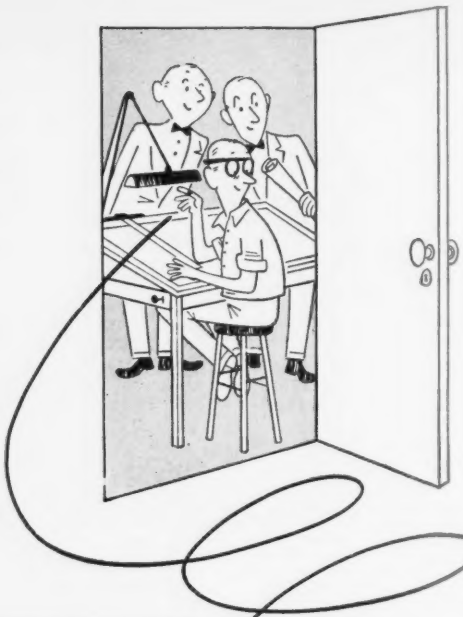
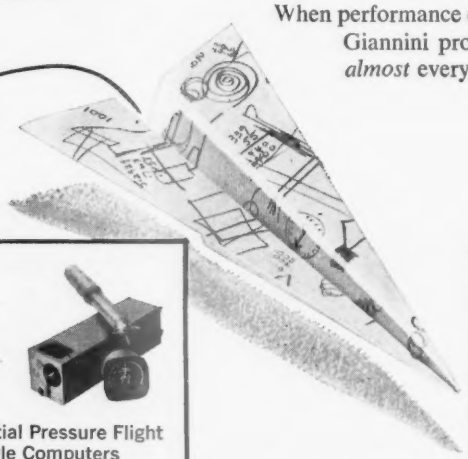


Giannini Instruments and Controls for almost every airborne application

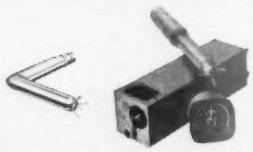
Whether single components or complex packaged systems, virtually all operational military aircraft (and civilian, too) use reliable Giannini precision-crafted instruments and controls.

When performance demands precision, specify Giannini products—they're available for *almost* every airborne application.

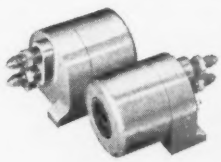


Accelerometers

Temperature Probes



Differential Pressure Flight Angle Computers

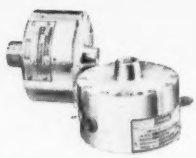


Low Pressure Transducers

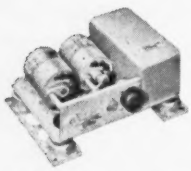
Gyro Instruments

Infinite Resolution Spiralpot Potentiometers

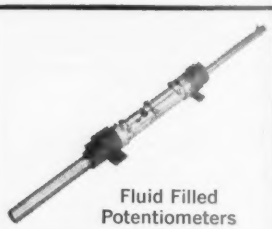
Aerodynamic Angle of Attack Transducers



High Pressure Transducers



Air Data Systems



Fluid Filled Potentiometers

Giannini

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Engineering positions are open for career-minded young men at several locations—write for details.

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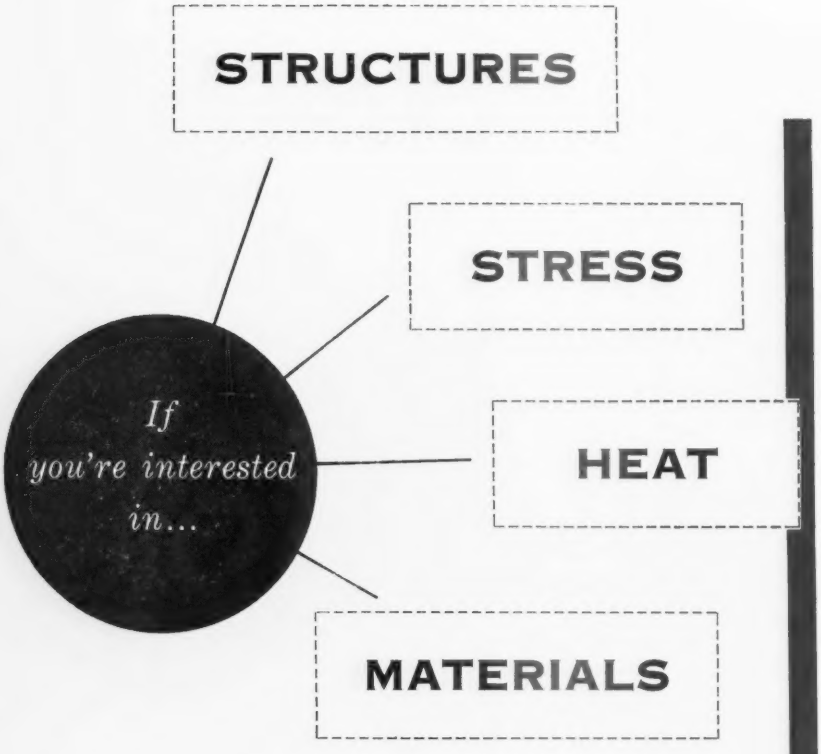
PRACTICE MAKES PERFECT— In 1957, as in 1776, one measure of effective defense is the true aim and steady skill of a nation's fighting men. To make American warriors proficient against complex modern weapons, Northrop Aircraft's subsidiary, Radioplane Company, produces targets like the rocket-powered RP-70 type, a light, low-cost drone, which simulates a high speed modern jet plane or missile at stratospheric altitudes. Like Northrop's new supersonic Air Force trainer airplane and Snark SM-62 intercontinental guided missile, the RP-70 is another example of the Northrop-Radioplane policy of "*security with solvency*" which applies advanced science and technology to deliver the maximum in national defense for the minimum in tax dollars.

NORTHROP

NORTHROP AIRCRAFT, INC. • HAWTHORNE, CALIFORNIA

Builders of the First Intercontinental Guided Missile



there's an exceptional opportunity for you at Hughes.

There are many excellent openings for mechanical and aeronautical engineers for challenging assignments in the areas of high-speed missiles, aircraft structures, and antennas. This work concerns developing practical solutions to both theoretical and actual problems of heat transfer, structural analysis and design, stress analysis, materials section, and instrumentation.

The projects at Hughes have both military and commercial potential. Men qualified for these activities are assured of a practically unlimited future in a career with the West's leading center for advanced electronics.

You owe it to yourself to investigate this opportunity to earn a top salary while working with leading scientists and engineers in the ideal climate of Southern California. Mail us your resume to qualify for personal interviews.

Scientific Staff Relations

HUGHES

Research and Development Laboratories
HUGHES AIRCRAFT COMPANY
Culver City
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A few of our openings include:

AERONAUTICAL ENGINEER
For aerodynamics consultation. Determination of aerodynamic loads for modifications to aircraft. Additional aeronautical engineering tasks such as stress, mechanical engineering, hydraulics, etc.

RESEARCH ENGINEER
To design and develop electro-mechanical servos and rate measuring systems for application in airborne instrumentation systems.

MECHANICAL ENGINEER
To handle the design of mechanical components related to laboratory work in the field of microwaves.

MECHANICAL ENGINEERS
To participate in the design and development of missiles, missile launchers, aircraft structure, component installation, environmental test equipment, hydraulic and general mechanical design.

AERONAUTICAL ENGINEERS
For the analysis and design of missile launching equipment for high-speed aircraft, including coordination and liaison with many major airframe manufacturers.

DYNAMICS ENGINEERS
To work on shock and vibration problems in an aerothermal environment. Also elasticians to work on advanced aerothermo-elastic problems associated with high-speed flight.

ENGINEER
For research related to the selection of materials and development of fabrication techniques.

These positions also available in the Research and Development activity at Tucson, Arizona.

Fenwal Introduces—

NEW, SMALL, LIGHT DIFFERENTIAL THERMOSTAT

Fenwal Solves Camera Compartment Problem, Comes Up With Control With Broad Applications

ASHLAND, MASS. — An aviation company in the habit of taking its temperature control problems to Fenwal asked Fenwal experts here how to control the temperature in a new plane's camera compartment.

Fenwal's experts solved the problem handily, and are making no secret of this: *Their solution, a brand-new differential thermostatic control, will find a thousand other applications — in the aviation industry and out.*

The device, weighing only 0.3 of a pound, consists of two midget Fenwal THERMOSWITCH® units and a relay — hermetically sealed in an integral stainless steel housing.

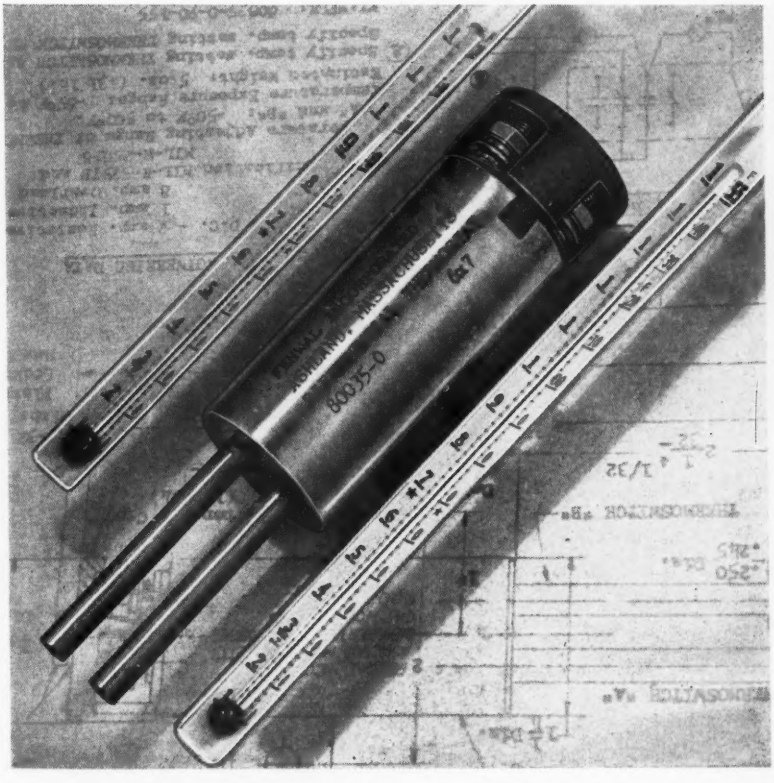
Camera Compartment Control

When it made its debut, the unit had only one purpose — to keep a camera compartment warmer than 90°F. and cooler than 155°F. It called for heat at the lower limit, and shut off heat at the upper one. It increased its own life and the life of the mechanisms it controlled by eliminating short-term cycling, by signalling for remedial action only at either limit of the acceptable temperature range.

Wide Applications

Actually, this control, which isn't much bigger than a .50 caliber machine gun cartridge, is a designer's dream, because it can be used to signal for any sort of action when an upper or lower temperature limit is reached. It can be factory set for limits anywhere from −50°F. to +500°F.

The relay rating at 28 volts D.C. is 2 amps resistive, 1 amp. inductive, and 8 amps overload. Due to high altitude performance requirements, the unit incorporates a three-terminal header and cover.

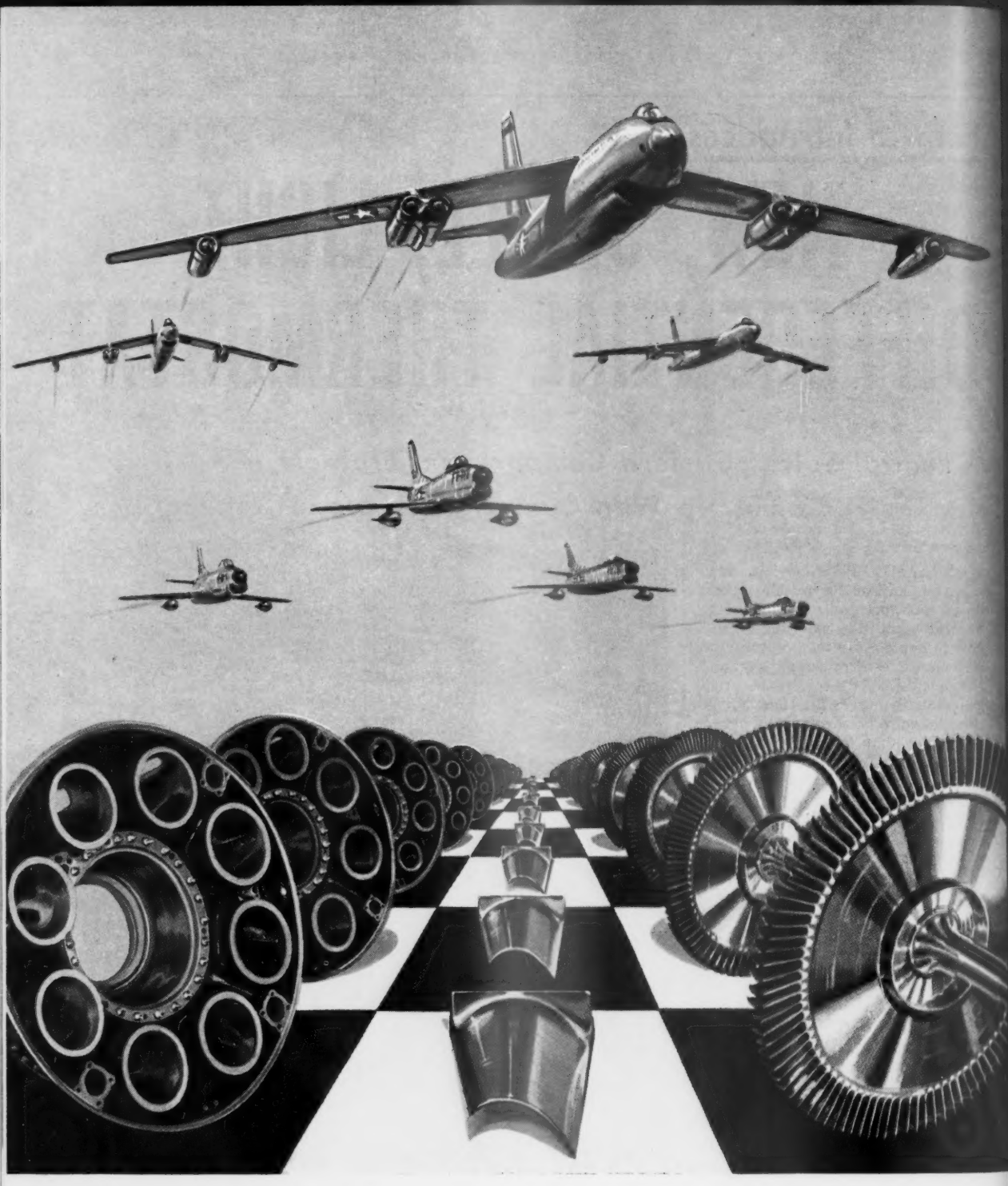


In the course of its development, the unit came by a name that doesn't begin to describe its versatility — the Fenwal Camera Compartment Over-heat Control. As happens again and again at Fenwal, experts here started with a specific problem, came up with a unit to solve it, and found that they had thereby increased the Fenwal Product line greatly, with a widely useful concept of temperature control.

Contact your local Fenwal sales engineer, or write to Fenwal direct to learn how this and other Fenwal developments may solve temperature control problems now facing you. **Fenwal Incorporated, Aviation Products Division, 172 Pleasant Street, Ashland, Massachusetts.**

Fenwal

CONTROLS TEMPERATURE ... *PRECISELY*



1,600,264 **Major and vital components for jet engines**

produced by Fairchild Engine Division—*in mass quantity, to highest precision standards*

Through skill, experience and production efficiency, Fairchild Engine Division manufactures such precision parts as turbine wheels, frames, diaphragms and turbine buckets for the jet engines of some of America's most powerful fighters and bombers. Subcontracting many other parts as well, Fairchild Engine Division has proved dependable production performance in mass quantity to highest precision standards.

Now in Fairchild's new plant at Deer Park, Long Island, this production capability is increased even more, and will be put to work wherever necessary to serve today's ever expanding aviation industry.

FAIRCHIL

ENGINE DIVISION • DEER PARK, L. I.,

A Division of Fairchild Engine and Airplane Corpora

...WHERE THE FUTURE IS MEASURED IN LIGHT-YE

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I.A.S. News Notes

February 1957

CHARLES J. McCARTHY (F), Chairman of the Board of Chance Vought Aircraft, Inc., has been appointed a member of the National Advisory Committee for Aeronautics to succeed Arthur E. Raymond (HF), Vice President - Engineering, Douglas Aircraft Company, Inc.

A NEW IAS CORPORATE MEMBER is Servomechanisms, Inc., with home offices at Post and Stewart Avenues, Westbury, L. I., N. Y.

LAST CALL: Candidates for the IAS Flight Test Engineering Fellowship have until March 1 to file applications. Qualifications are a B. S. in Engineering (before June 1957) and U. S. citizenship. Forms are available by a request in writing, endorsed by a sponsoring reference, to Flight Test, Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, New York.

NATIONAL MEETINGS CALENDAR

3/14-15	Flight Propulsion Meeting, (Classified), Hotel Carter, Cleveland.
6/17-20	National Summer Meeting, Biltmore Hotel, Los Angeles, California.
8/6-10	Naval Aviation Meeting, U. S. Grant Hotel, San Diego, California.
9/1-16	Sixth International Aeronautical Conference, Royal Aeronautical Society and IAS, London and Folkestone, England.
11/7-8	Weapons System Management Meeting, Statler-Hilton Hotel, Dallas.
11/25-26	International Meeting, Canadian Aeronautical Institute and IAS, Montreal, Quebec, Canada.
12/17	Wright Brothers Lecture, Dept. of Commerce Auditorium, Washington
1/27-31	Twenty-Sixth Annual Meeting, Sheraton-Astor Hotel, New York.

JOINT MEETINGS CALENDAR

3/11-15	1957 Nuclear Congress, Convention Hall, Philadelphia, Coordinated by Engineers Joint Council.
4/14-16	National Symposium on Telemetering, Philadelphia, Pennsylvania.
5/13-15	IRE National Conference on Aeronautical Electronics, Dayton, Ohio. IAS Session on Cooling.
5/27-29	National Telemetering Conference, Hotel Cortez, El Paso, Texas. Sponsored by IAS, ISA, and AIEE.
6/19-21	1957 Heat Transfer and Fluid Mechanics Institute, California Institute of Technology, Pasadena. Cosponsored by IAS.

I.A.S. News Notes (con't.)

REGIONAL STUDENT CONFERENCE SCHEDULE

Mar. 29-30 Northeastern: Princeton University, Princeton, New Jersey.

Apr. 8 Indianapolis: Purdue University, West Lafayette, Ind. Sponsored by Indianapolis Section of IAS.

Apr. 24-26 St. Louis: St. Louis, Missouri. Sponsored by St. Louis Section.

Apr. 25-27 Texas: Fort Worth. Sponsored by Texas Section.

May 3-4 Middle Atlantic: University of Virginia, Charlottesville, Virginia.

May 7 Detroit: Wayne State University. Sponsored by Detroit Section.

SECTION MEETINGS CALENDAR

Feb. 11 Indianapolis Section: Dinner Meeting, Athenaeum Turners Club, 7 p.m. (Social Hour at 6:30). "Pneumatic Control Components for Jet Engines" by Edward J. Knight, Jr.

Feb. 11 Texas Section: Joint Dinner Meeting with SAE, Lucas B & B Restaurant, 8 p.m. (Social Hour at 7). "Missiles - Past, Present and Future" by Walter LaBerge.

Feb. 12 Washington Section: Dinner Meeting, Occidental Restaurant, 6 p.m. "Long Range Trends and Immediate Problems in Air Traffic Control" by David Thomas and James Anast.

Feb. 12 Los Angeles Section: Specialist Meeting, IAS Building, 8 p.m. "Low Reynolds Number Experiments in an Axial Turbomachine" by Joseph Neustein.

Feb. 13 Niagara Frontier Section: Specialist Meeting, Cornell Aeronautical Lab Auditorium, 8:30 p.m. "Design Trends in Future Aircraft Structures" by Wilfred M. Dukes.

Feb. 14 Cleveland-Akron Section: Dinner Meeting, Liedertafel, Akron, 7 p.m. (Social Hour at 6). "Physiological Problems of Space Flight" by Hermann J. Schaefer.

Feb. 19 Boston Section: Specialist Meeting, MIT, Room 35-225, 8 p.m. "Aircraft Engineering and Small Submarines" by T. F. Hammer, Jr.

Feb. 19 Dayton Section: Dinner Meeting, Ember's Supper Club, 6:30 p.m. "Ram Air Windmills for Emergency Aircraft Power" by J. R. Kessler.

Feb. 19 Hagerstown Section: Annual Dinner Meeting, Tortuga Restaurant, 7 p.m. "History of Aeronautics" by Paul Edward Garber.

Feb. 19 San Diego Section: Specialist Meeting, IAS Building, 8 p.m. "Teamwork in Guided Missile Development" by Ludwig Rote.

Feb. 22 Texas Section: Specialist Meeting, Arlington State College, Engineering Auditorium, 8 p.m. "Flight Safety Symposium."

Feb. 26 Los Angeles Section: Specialist Meeting, IAS Building, 8 p.m. "High Intensity Acoustical Test Facility, Loud Speakers and Siren" by R. June and R. M. Belcher.

Mar. 12 Washington Section: Dinner Meeting, Occidental Restaurant, 6 p.m. "Future Technical Trends in Air Transportation" by G. F. Worley.

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IAS News

A Record of People and Events of Interest to Institute Members

400 Hear Twentieth Wright Brothers Lecture

Sir Arnold Hall, British Scientist, Gives Views on Research and Development and Technical Issues Affecting Civil Aviation

THE TWENTIETH WRIGHT BROTHERS LECTURE, marking the fifty-third anniversary of the first airplane flights made by Orville and Wilbur Wright at Kitty Hawk, N.C., was presented by the IAS in Washington, D.C., on December 17. The 1956 Lecturer was Sir Arnold Hall (FRAeS) of England.

An audience of about 400 aeronautical engineers, research scientists, and technical specialists heard Sir Arnold deliver a paper on "Some Comments on Current Aviation Topics" in the auditorium of the U.S. Chamber of Commerce Building.

Sir Arnold is Technical Director and Scientific Advisor and Consultant for the Hawker Siddeley Group Limited, London. He gained world recognition for his work in connection with the inquiry into causes of the Comet air liner crashes. It was under his direction that the task of nearly complete reconstruction of a crashed Comet was undertaken and the cause of the accidents established.

Chairman of the afternoon presentation was Edward R. Sharp, 1956 President of the IAS and Director of Lewis Flight Propulsion Laboratory of the National Advisory Committee for Aeronautics. He introduced Sir Arnold to the audience.

Prepared discussions following the lecture were presented by Clifford C. Furnas (F), U.S. Assistant Secretary of Defense (Research and Development); William Littlewood (F), Vice-President, Research and Development, American Airlines, Inc.; Hugh L. Dryden (HF, HM), Director, National Advisory Committee for Aeronautics; and T. P. Wright (HF), Vice-President for Research, Cornell University.

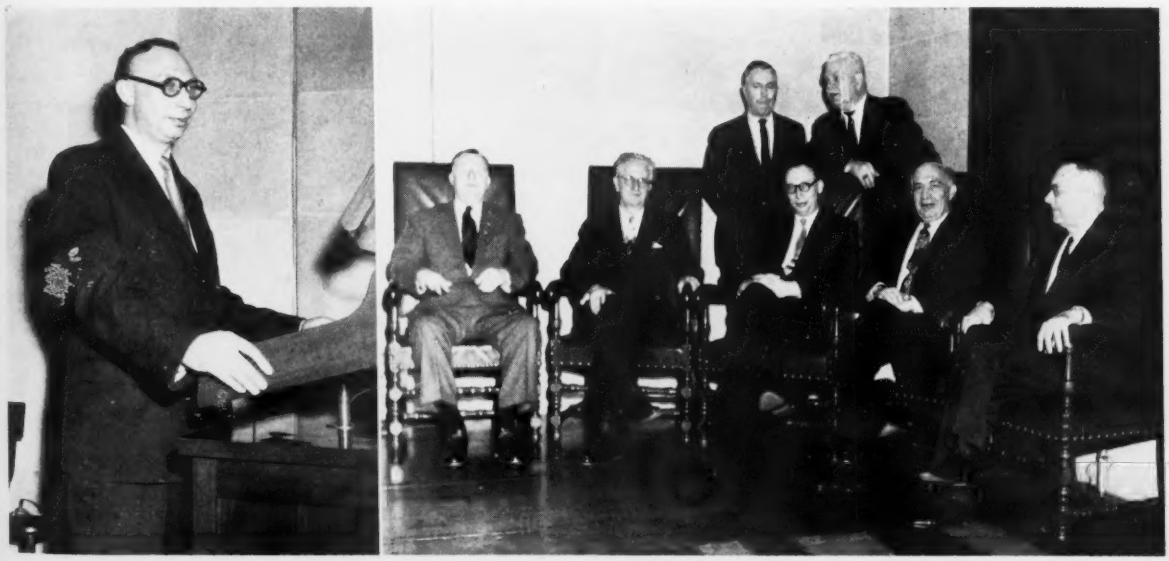
Sir Arnold divided his lecture into two parts—administrative matters affecting research and development and current technical issues particularly affecting civil aviation.

As the topic of his lecture implied, Sir Arnold touched upon many subjects of importance to many segments of aviation. He pointed out that three technical matters, of the many that affect civil aviation, are of particular influence: the direct operating economy attainable, the integrity and useful life of structures, and the noise nuisance.

The lecture was not repeated in other areas of the country, Sir Arnold having announced when invited to present the lecture that he would be unable to speak other than in Washington. His complete paper, however, will be published in an early issue of the JOURNAL OF THE AERONAUTICAL SCIENCES.

The Wright Brothers Lecture is presented annually on December 17. It is endowed by the Vernon Lynch Fund and was established in 1937. Lecturers are distinguished aeronautical scientists.

Sir Arnold Hall delivers Wright Brothers Lecture. Discussers and principals for lecture pictured here include (*seated*) William Littlewood, T. P. Wright, Sir Arnold, C. C. Furnas, H. L. Dryden, (*standing*) S. P. Johnston, and E. R. Sharp.

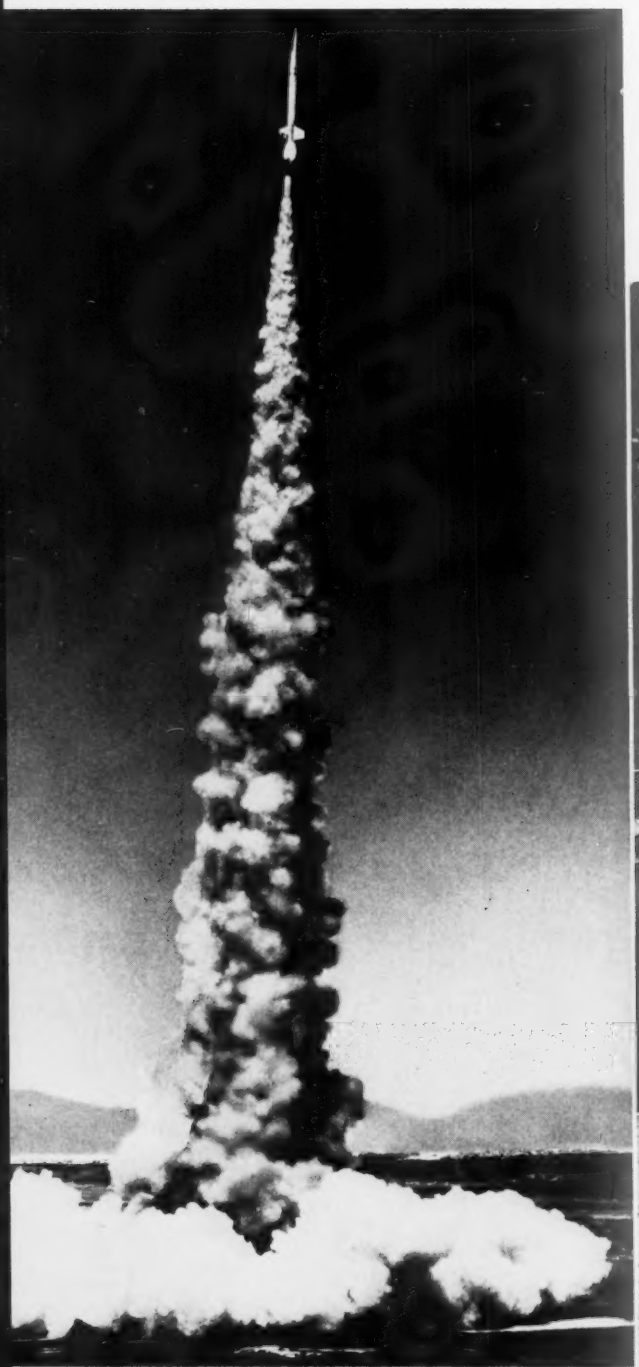


Missile Symposium

Air Force, Army, and Navy Present Briefings and Demonstrations of Missile Developments to IAS Corporate Member Representatives at Holloman and White Sands.

ON NOVEMBER 19 AND 20, the Air Force, Army, and Navy joined forces in presenting an enlightening missile symposium to some 100 security-cleared representatives of the Institute's Corporate Member family. Briefings on present and future-planned missiles, plus firings of various current types, were included in the agenda of the 2-day meeting.

Major Gen. L. I. Davis, USAF, Commander of Holloman Air Development Center, and Col. Otto R. Haney, USAF,



The Aerobee sounding rocket (*above*), developed by Aerojet-General Corp., takes off at White Sands. (*Top, right*) IAS Group is welcomed by Major Gen. L. I. Davis at HADC. (*Center*) Visitors huddle behind busses to escape chill winds on the range at WSPG. (*Bottom*) Balmier skys prevail as a missile is sent aloft at Holloman.

Chief of Staff, HADC, acted as hosts for the first day's program. In addition to classified briefings and demonstrations, the tour included visits to the Lockheed, Bell, Hughes, and Radioplane facilities located at the Center. A luncheon at the NCO Open Mess, a late-afternoon visit to the White Sands National Monument, and an evening cocktail party and western-style barbecue at the Officers Club rounded out the impressive day's program by the Air Force at Holloman.

The Army took charge of the second day's schedule and put on an equally impressive show despite less favorable weather conditions on the range. Major Gen. W. E. Laidlaw, USA, commanding general of White Sands Proving Ground, welcomed the group and personally directed the day's activities. Briefings were given by Col. B. R. Luczak, chief of the Integrated Range; Capt. W. H. Knipe, Corporal project officer; Lt. Col. James P. Hamill, chief of Ordnance Mission; Capt. W. H. Clark, Nike project officer; Capt. V. W. Hammond, of the IM-70 (Talos) weapons system; and Capt. D. S. Hanline, Hawk project officer.

A briefing on the Navy's Talos weapons system was given during the afternoon by Lt. A. F. Condliffe, USN. Motion picture films on missile systems, actual firings of various missiles, and a luncheon in the Rocket Room of the Officers Club completed the day's program.

CAI-IAS Third Joint Conference Held in Toronto

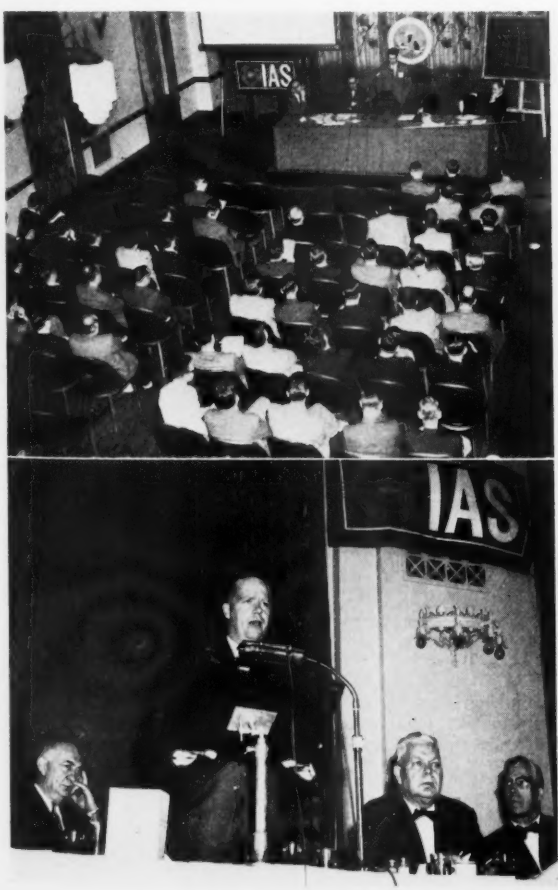
THE THIRD JOINT MEETING of the Canadian Aeronautical Institute and the IAS, November 26, 27, turned out to be the largest of these annual conferences held to date. A total registration of some 800 people indicates the growing interest in, and importance of, these get-togethers with our Canadian friends and counterparts.

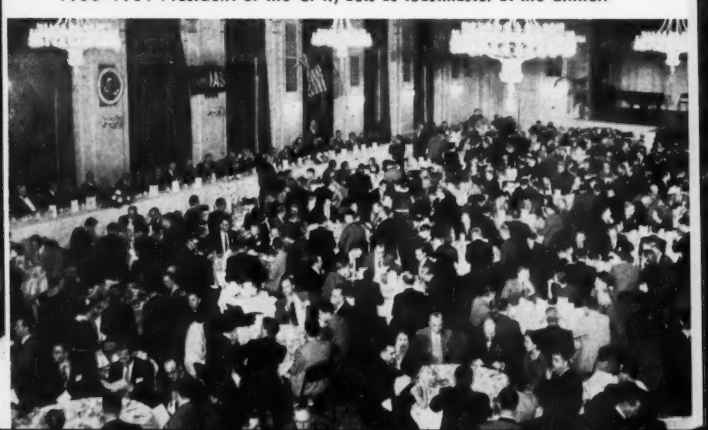
Twelve papers were delivered during the four technical sessions on the subjects of Test Flying, Quality Control, Electronics, and Missiles. Since the majority of these papers are being published in the CAI *Journal*, they will not appear in the REVIEW. However, preprints of many of them are still available through the Institute's Preprint Department. (See papers listed on p. 82.)

The second annual W. Rupert Turnbull Lecture was also delivered during the first afternoon of the conference. This year's lecturer, Simon Ramo, Executive Vice-President of The Ramo-Wooldridge Corporation, presented a very comprehensive paper on "The Guided Missile as a Systems Engineering Problem." As customary, this lecture is being published by the Canadian Aeronautical Institute.

The Conference Dinner was held on the evening of November 26 in the Concert Hall of the Royal York and was attended by approximately 500 guests. T. E. Stephenson, this year's president of the CAI and Sales Engineering and Service Manager for Canadian Pratt & Whitney Aircraft Company, Ltd., served as toastmaster and introduced the speakers. C. C. Furnas, Assistant Secretary of Defense, Research and Development, delivered the principal address in which he presented some interesting facts and philosophies on world problems—present and future.

E. R. Sharp, 1956 IAS President, spoke briefly on behalf of the Institute and justly praised the staff people and officers of the CAI for the splendid job that had been done on this Conference. He also pointed up the phenomenal growth of the CAI and congratulated all concerned on the manner in which its activities and policies have developed.





Technical sessions (*above, left*) and dinner (*below*) are well attended at Toronto's Royal York Hotel. (*Left*) T. E. Stephenson, 1956–1957 President of the CAI, acts as toastmaster at the dinner.

Aeronutronic Systems, Inc. New Corporate Member of IAS

Aeronutronic Systems, Inc., a subsidiary of Ford Motor Company, formed in May, 1956, to design, develop, and manufacture weapons systems, subsystems, and components, has joined the Institute as a Corporate Member. Manufacture is for military and commercial application.

The new organization is a successor to Systems Research Corporation, a scientific consulting firm. Scientists and engineers of the old firm will form the nucleus, with expanded staff and facilities being provided.

Specific study will be on missile development including aerodynamics, ballistics, guidance and control, handling and launching, propulsion, and warheads.

Ernest R. Breech, Chairman of the Board at Ford, also will be Chairman of the Board at Aeronutronics. Offices are at Glendale, Calif.

Institute Is Cosponsor of 1957 Nuclear Congress

The Institute again this year will cosponsor the 1957 Nuclear Congress to be held March 11–15, in Convention Hall, Philadelphia.

Included in the Congress are four major elements: the Second Nuclear Engineering and Science Congress, International Atomic Exposition, Fifth Hot Laboratories and Equipment Conference, and the National Industrial Conference Board's Fifth Conference on Atomic Energy in Industry.

Programs have been sent to all Section Chairmen and to all members of Middle East Coast Sections. More programs are available by writing to the IAS, Meetings Committee, 2 East 64th Street, New York 21, N.Y.

Necrology

Stanley U. Benscoter

Stanley U. Benscoter (AF), Aerophysics Specialist with Aerophysics Development Corporation, died in May. He was 45.

A native of Nevada, Mo., Dr. Benscoter became a member of the IAS in 1945. He attended Kansas City Junior College, University of Illinois, and California Institute of Technology where he received his Ph.D. in Aeronautics.

Dr. Benscoter served as an Aeronautical Engineer with the Naval Bureau of Aeronautics and with NACA Structures Division, Langley Field, Va., and had been a Consultant on stress analysis of delta wings in the Aerophysics Laboratory of North American Aviation, Inc. He had published some 15 technical papers on structures.

His versatile background included design of steel and reinforced concrete structures for flood control projects in the Midwest, design of flood control projects at Army camps and airports, design of floating bridges, mathematical research for improvement of specifications for structural design, independent research in aeronautical structures, and research on stress and aeroelastic analysis with the Caltech Analog Computer.

Dennis J. Phelan

News of the death of Dennis J. Phelan (TM), Supervisor of Engineering Aerodynamics at Trans World Airlines, Kansas City, Mo., has been received.

Mr. Phelan attended St. Louis University where he earned a degree in meteorology in 1947. Later that year he enrolled at Parks College, St. Louis, and was graduated in 1950 with a Bachelor's degree in aeronautical engineering. He also studied meteorology at Massachusetts Institute of Technology.

During World War II, Mr. Phelan was a Navy Aerological Officer forecasting for continental and oceanic flights, and for 4 months in 1946 he was Commanding Officer of a Naval Unit in Chungking, China.

He joined McDonnell Aircraft Corporation as an aeronautical engineer in 1950 and worked at general aircraft aerodynamics, wind-tunnel testing, and general design, before joining TWA.

He also was a member of the American Meteorological Society.

NEWS OF MEMBERS

▶ **H. M. Chamness, Jr.** (TM), Development Engineer, Marquardt Aircraft Company, Van Nuys, Calif., has been assigned to the firm's Dayton office as Company Representative.

▶ **Robert C. Curry** (M) has been appointed Manager—Aircraft Structures Engineering of American Airlines, Inc., Maintenance and Engineering Department. He formerly was Project Engineer in the department.

▶ **A. La Vielle Lawbaugh,** (AF), formerly Supervisor—Project Design Unit at North American Aviation, Inc., Missile Development Division, has been promoted to Advanced Engineering Group Leader in the division.

▶ **Peter Tauson** (AF), formerly Research Engineer at the National Supply Company, has been promoted to Assistant Director of the firm's Research Engineering Department.

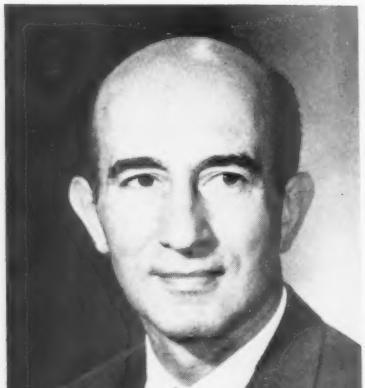
Members on the move . . . .

This section provides information concerning the latest affiliations of IAS members. All members are urged to notify the News Editor of changes as soon as they occur.

Shepard M. Arkin (M), formerly with the Navy Bureau of Aeronautics, has been appointed Staff Engineer at Raytheon Manufacturing Company's Missile Systems Division.

2nd Lt. John B. Clark (TM), former Associate Engineer at The Johns Hopkins University Applied Physics Laboratory, is on active duty with the USAF, Air Research and Development Command. Lieutenant Clark is Assistant Chief of the Aircraft Environmental Protection Section in the Aeronautics and Propulsion Division.

Lee J. Doyle (M) has been appointed Manager of Field Engineering for the Maxim Silencer Company of Hartford, Conn., a subsidiary of Emhart Manufacturing Company. He formerly was Manager—Aircraft Sales and Engineering, Industrial Sound Control Department, Koppers Company, Inc.



Eugene J. Manganiello (AF), Assistant Director, Lewis Flight Propulsion Laboratory, NACA, has been awarded a scholarship by alumni of the American Management Association's management course to attend the course in New York City. Mr. Manganiello was selected in competition among top-level Federal employees who were nominated by their agencies for one of the eight annual scholarships.

Herbert Ray Graham (M), formerly Development Engineer at the Southern California Cooperative Wind Tunnel, has entered the California Institute of Technology where he will be Wind Tunnel Supervisor of the school's 10-ft. wind tunnel and will also pursue graduate studies.

George Kass (AF) has joined Barium Steel Corporation's subsidiary, East Coast Aeronautics, Inc., as Senior Project Engineer. He formerly was Assistant Senior Project Engineer at Fairchild Engine and Airplane Corporation's Stratos Division.

William T. Schwendler (HF), Senior Vice-President and a founder of Grumman Aircraft Engineering Corporation, has been elected to New York University's Board of Trustees.

John N. Kerr (M), former Chief of Associated Projects at Northrop Aircraft, Inc., has been appointed Vice-President of the Los Angeles engineering firm, Horkey Associates.

Comdr. Oscar E. Loeser (AF), former Western District Maintenance Representative for the Bureau of Aeronautics, has been assigned to the staff of the Naval Air Material Center in Philadelphia.

John F. M. Oram (M), formerly Structural Designer for Bristol Aeroplane Co., Ltd., Filton, England, has joined Lockheed Aircraft Corporation's California Division.

W. Eugene Rohman (AF) has been named Manager—Operations Accounting Services at Hamilton Standard Division of United Aircraft Corporation. Mr. Rohman had been Head of the Operations Research Section in the Research Department.

Gersten L. Schackne (TM) has joined the newly formed American Aerophysics Corporation of El Segundo, Calif., as a Stress Engineer. He formerly was a Stress Analyst with Aerophysics Development Corporation.

George E. Solomon (M), of The Ramo-Wooldridge Corporation, has been assigned to the position of Head, Aerophysics Department, Aeronautical Research and Development Staff, Guided Missile Research Division.

Adolph K. Thiel (M) is Assistant Program Director for the Thor Intermediate Range Ballistic Missile Program in the Guided Missile Research Division of The Ramo-Wooldridge Corporation. Before this recent appointment, Dr. Thiel was Senior Staff Member in the same department.

Gene H. White (M), a Consulting Engineer in fluid systems, aircraft and missiles, has joined Leach Corporation as Manager of the Pressure Switch Division.

E. R. Van Driest (M) has been appointed Chief Scientist of Technical Sciences for the Missile Development Division of North American Aviation, Inc. Dr. Van Driest formerly was Staff Specialist in the Aerodynamics Section of the Division.

CORPORATE MEMBER NEWS

• **Aeroquip Corporation** reports elimination of troublesome tieing and untieing of rope knots in cargo tie-down and other applications through use of its new Ropelock. For three eighths of an inch manila or nylon rope, it automatically locks tension at whatever maximum pull is exerted without slackening or backlash. Load can be released by pressing down on the cam. . . .A new *Aircraft Catalog No. 101*, including engineering data on the firm's low-, medium-, and high-pressure hose assemblies, has been issued. The catalog also contains assembly and installation instructions and a conversion chart showing corresponding military designations for parts. It may be obtained from The Advertising Department, Aeroquip Corporation, Jackson, Mich.

• **Allis-Chalmers Manufacturing Company** has opened a branch office of its Industries Group in Allentown, Pa., under the management of Ralph L. Haney.

• **Aluminum Company of America** announced it has clad aluminum produced by impact extrusion with a thin surface which provides cathodic corrosion protection, facilitates finishing, or makes joining easier. The process is reported to make possible use of impact aluminum in water filters, small water tanks, steam traps, electrical cases, fittings for home hot water heaters, and process industry operations where corrosive solutions or atmospheres are severe.

• **American Steel & Wire Division, United States Steel Corporation,** announced the following promotions: Harry L. Jenter, formerly Cleveland District Manager of Operations, to Operations Vice-President; Walter L. Longnecker, former Superintendent of the division's Cuyahoga Works, to Cleveland District Manager of Operations; and James J. Dalton from Superintendent of the Cold Roll Department to General Superintendent of Cuyahoga Works.

• **Amphenol Electronics Corporation** has distributed a new industrial electronic components catalog designed to meet the needs of component users. Copies are available from the firm's authorized distributors. . . .The firm has announced two new Teflon coaxial cables with nonmagnetic conductors. The new cables find use where both high temperature and nonmagnetic qualities are desirable.

• **Avien, Inc.,** has appointed Scott W. Donaldson its company representative in Washington, D.C. Brian Engineering, Ltd., Montreal, has been appointed Avien's sales and engineering representative in Canada.

• **Bell Aircraft Corporation . . .** Four executives have been appointed to new posts in the Aircraft Division: John W. Rane, Jr., Director of Engineering and Sales; George D. Ray (AF), Chief Engineer; Stanley W. Smith (AF), Chief Project Engineer; and John J. Weisbeck, Jr., Contracts Manager.

• **Bendix Aviation Corporation** has formed a new Systems Division at Ann Arbor, Mich., to concentrate on weapons systems requirements of the Department of Defense. The firm will construct a large laboratory and engineering building near the University of Michigan's North Campus. . . .International Division has received an order for Bendix C-band airborne weather radar for installation in the Constellation fleet of Varig Airlines of Brazil . . . .Eclipse-Pioneer Division has created a new post, Sales and Service Representative, and has appointed B. William Lalush to the job. . . .Products Division has laboratory and engine tested a new magnetic amplifier control system for very high thrust gas-turbine engines. Designed to solve fuel metering and engine control problems at Mach 3 speeds and 75,000-ft. heights, the system uses magnetic and hydraulic amplifiers to sense numerous engine parameters, compute changes in engine control variables for optimum thrust and fuel consumption, and motivate changing engine fuel flow and geometry. . . . Radio Division announced that Northeast Airlines has bought Bendix RDR-1 weather radar for new aircraft on its planned Boston–New York–Miami run. Capital Airlines' Viscounts also will be equipped with RDR-1 radar. . . .Red Bank Division has appointed William Sendell General-Products Production Manager. A new power transistor that will replace two tubes, vibrator, and power transformer in a car radio is in production at this division. . . .John P. Anderson has been appointed Project Engineer in charge of the Hydraulic Servo Valve Engineering Group at Pacific Division. Leo E. Gatzek has been made Supervisor of Heat Treat-

(*Continued on page 87*)

IAS PRESIDENT

1957

Mundy I. Peale

President
Republic Aviation Corporation

1956

Edward R. Sharp

Director, Lewis Flight Propulsion
Laboratory, NACA

Editorial

Once again the Institute welcomes as its President the head of a great aircraft manufacturing organization. It is always gratifying to us that men of Mundy Peale's caliber in industry have sufficient interest in the work of this Institute to take on their already overburdened shoulders the duties of the presidential office. This means, by implication, that the Institute stands for something more in their minds than a resounding name—an organization organized for the sake of its own organization. They recognize that industry progresses by our common effort. We help to provide more and better engineers. In doing so we progress toward our common goal—a stronger America.

One of the special duties of the IAS President during 1957 is to head the American delegation to the Sixth International Conference with The Royal Aeronautical Society of Great Britain in September. In this department Mundy Peale is eminently well qualified to maintain the standards and traditions set by past presidents Bassett, Burden, and Richardson when they led IAS delegations overseas.

As an officer and a member of the Council for the past year, our President already has considerable knowledge of the workings of this organization. We feel that we can draw upon his great background of business and management experience to improve the effectiveness of our own operations in providing essential services to our membership. Every member of the staff pledges him the fullest cooperation during the year ahead. We are glad to have him aboard.

"Ray" Sharp made many new friends for the Institute during his presidential year. His genial and informal approach puts people instantly at ease and reduces the potential "stuffiness" of any gathering to a minimum. In spite of his heavy day-to-day responsibilities as Director of a great research laboratory, he was willing to take time to travel to many parts of the country to attend our national (and international) meetings and to look in at many of our Sections and Student Branches. His interest in the internal affairs of the Institute (which dates back through his years as a member of the Council) provided the staff with invaluable advice and assistance in the daily conduct of our business. We all owe him a vote of thanks for his very real contribution toward the work of this organization. We are glad that our By-Laws provide that the retiring President remain as a member of the Council during the year following his term of office. We are certain, however, that we can count on Ray's help and support far beyond any period of time specified in our rules and regulations!

S. P. J.

Beryllium as an Aircraft Structural Material†

George A. Hoffman,* The RAND Corporation

Review of a study on beryllium, including structural evaluation, economic considerations, and a hypothetical example, with suggestions for research.

Introduction

For the past year The RAND Corporation has been evaluating beryllium as a material for aircraft structures. This study of beryllium stemmed from RAND's function as a scientific adviser to the Air Force on long-range planning and from its role as a monitor of the state-of-the-art of aeronautics. RAND has been investigating several areas where significant improvements could be made, including the technology of aircraft structures. This study is an attempt at finding large-scale improvements in structural techniques, somewhat analogous to the improvement, for example, afforded by boundary-layer control to the technology of aerodynamics.

Structural design comprises two primary factors—the configuration of the construction and the material used in the construction. Of these two, the greater improvement in design lay in improving the material. Several alternatives came to mind for improving aircraft materials: improving properties of existing alloys of metals, developing superior alloys of conventional metals, inventing new materials by combining different materials while utilizing the best properties of each, or utilizing new (to aircraft usage) metallic elements. The utilization of new metallic elements was selected as the best alternative. Beryllium appeared to be the most promising of the metals for which relevant data existed.

This paper reviews the advantages and drawbacks of the use of beryllium in aircraft structures. The conclusions enumerate the problems still to be solved and suggest possible ways of solving the particular problem of brittleness.

How Beryllium Was Chosen

The structural worth of metallic elements may be evaluated by comparing the weights of aircraft structures assumed to be made of such metals. Relative merits of different materials become apparent in a comparison of structural weights, and the method of obtaining the weights lends itself to many simplifications.

One of the simplifying assumptions is that moderate alloying of an element does not perceptibly affect its density or its modulus of elasticity. The assumption that the density and modulus of elasticity of an unalloyed metallic element are close to the density and modulus of elasticity of its potential alloys permits the comparison of potentialities of many elements for which few data are available. Another convenient simplification is to assume structures composed of thin-walled elements that fail by elastic buckling. This allows a comparison of the elements based only on their density and modulus of elasticity. A more accurate structural comparison (such as the one in the subsequent portions of this paper) should account for the complete stress-strain characteristics of the metal.

Thin-walled structures designed by buckling criteria were chosen as one basis of comparison because they comprise a large portion of conventional aircraft structures. About 60 to 80 per cent of the structural weight is usually made up of sheet-stringer panels, minimum-gage plates, wide beams and columns, or similar thin-walled elements. When such compression-loaded elements of equal strength are designed close to optimum dimensions, their weight is roughly proportional to the density of the material divided by the square root of its modulus of elasticity (see reference 1, pp. 74, 75).

Aluminum is used here as the basis of comparison of the metals, and an aluminum compression structural element is considered to weigh unity. Then the relative weight of structures made of various metallic elements becomes approximately equal to

$$\frac{\text{density of element}}{\text{density of aluminum}} \times \sqrt{\frac{\text{modulus of elasticity of aluminum}}{\text{modulus of elasticity of element}}}$$

Metallic elements whose density and modulus of elasticity at room temperature are reasonably well known are listed in Table 1. They are arranged by atomic number, and their relative weights are shown as calculated by the above formula. Where known, the

† The author gratefully acknowledges the cooperation of W. R. Micks who coauthored the original RAND report.

* Engineer, Aeronautics Department.

ultimate tensile strength of the element or its alloys is also shown. The data come either from reference 2 or from subsequent literature on particular elements. Eight elements are omitted because their melting points are close to room temperature.

The pattern shown in Fig. 1 is obtained when the relative weight of structures of various metals is plotted against the atomic number of the metals. Arranging the relative weights by atomic numbers shows a definite tendency for the lower-numbered elements to result in lighter structures. This apparent tendency for structural weight to be proportional to atomic number seems to exist at temperatures other than 70°F.; Fig. 2, which is a plot for structures at 1,200°F., exhibits a similar tendency. At this temperature the structure of unit weight was assumed to be steel. In both Figs. 1 and 2, elements whose melting points were close to the temperature in question were omitted.

The trend for weights to be roughly proportional to atomic number is an interesting feature that should

TABLE 1
Structural Properties of Metallic Elements

Symbol	Element	Atomic Number	Density (lb./in.³)	Modulus of Elasticity (millions of psi)	Relative Weight	Ultimate Tensile Strength
Li	Lithium	3	0.019	2	0.44	20,000
Be	Beryllium	4	0.066	44	0.327	125,000
B	Boron	5	0.083	50	0.38	76,000
Mg	Magnesium	12	0.066	6.5	0.84	60,000
Al	Aluminum	13	0.100	10.6	1.00	100,000
Si	Silicon	14	0.084	17	0.67	...
Ca	Calcium	20	0.056	3.5	0.97	9,000
Ti	Titanium	22	0.170	16.7	1.35	180,000
V	Vanadium	23	0.217	24	1.44	150,000
Cr	Chromium	24	0.260	45	1.26	60,000
Mn	Manganese	25	0.268	23	1.82	50,000
Fe	Iron	26	0.283	29	1.71	300,000
Co	Cobalt	27	0.327	32	1.88	130,000
Ni	Nickel	28	0.322	31	1.88	200,000
Cu	Copper	29	0.324	18.5	2.46	90,000
Zn	Zinc	30	0.258	15	2.17	...
Ge	Germanium	32	0.194	12	1.82	...
As	Arsenic	33	0.207	11	2.03	...
Sr	Strontium	38	0.094	2.5	1.94	...
Zr	Zirconium	40	0.231	12	2.17	88,000
Cb	Columbium	41	0.310	23	2.10	150,000
Mo	Molybdenum	42	0.369	52	1.66	180,000
Tc	Technetium	43	0.415	59	1.76	...
Ru	Ruthenium	44	0.450	63	1.85	...
Rh	Rhodium	45	0.450	55	1.98	...
Pd	Palladium	46	0.434	17	3.43	71,000
Ag	Silver	47	0.379	11.2	3.69	50,000
Cd	Cadmium	48	0.313	10	3.22	14,000
Sn	Tin	50	0.264	7.8	3.07	...
Sb	Antimony	51	0.239	11.3	2.32	1,500
Te	Tellurium	52	0.225	6	2.99	...
Ba	Barium	56	0.130	2	2.99	...
La	Lanthanum	57	0.222	7	2.73	...
Ce	Cerium	58	0.253	5	3.69	...
Hf	Hafnium	72	0.411	12.1	3.84	...
Ta	Tantalum	73	0.601	27	3.76	130,000
W	Tungsten	74	0.697	60	2.93	300,000
Re	Rhenium	75	0.743	75.2	2.79	280,000
Os	Osmium	76	0.813	83	2.89	...
Ir	Iridium	77	0.815	78	3.01	...
Pt	Platinum	78	0.775	24	5.15	140,000
Au	Gold	79	0.698	12	6.57	35,000
Pb	Lead	82	0.410	3.8	6.85	8,000
Bi	Bismuth	83	0.354	4.6	5.37	2,500
Th	Thorium	90	0.422	22	2.93	50,000
U	Uranium	92	0.676	30	4.02	50,000

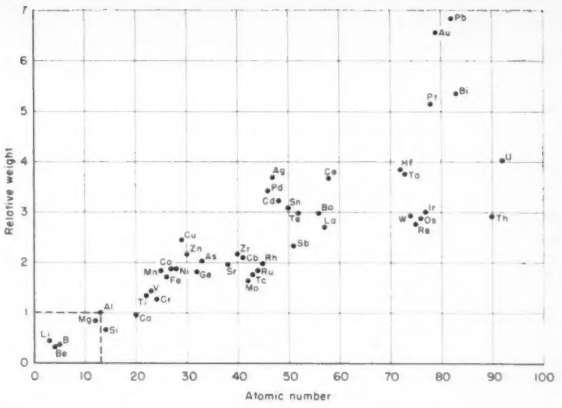


FIG. 1. Relative weights of thin-walled structures made of various metals, room temperature.

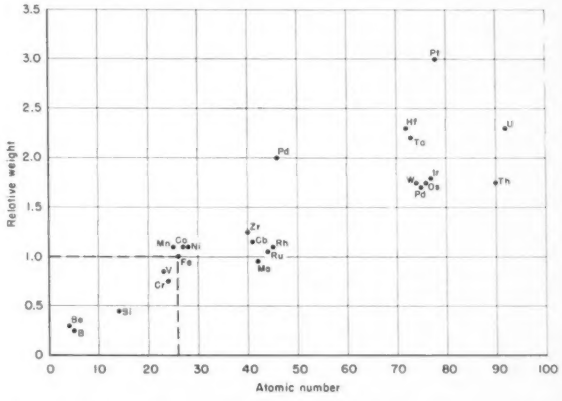


FIG. 2. Relative weights of thin-walled structures made of various metals, 1,200°F.

direct attention to the lower-numbered elements. Lithium, beryllium, and boron appear to be the metals of greatest interest for aircraft structures, and of these beryllium gives the lightest structure. Beside this advantage beryllium also appears to have fewer drawbacks for use in aircraft structures than either lithium or boron. Lithium, for example, has a low melting point (367°F.); consequently, it creeps under extremely low stress at room temperature. Also, it corrodes rapidly in air and reacts readily with water. Boron, on the other hand, has a high melting point (4,200°F.) and is inert to air and water, but it has so far exhibited extreme brittleness.

In summary, beryllium seems a logical choice for closer scrutiny when one notes a logical ordering of the structural worth of the metallic elements. Although the ordering should be interpreted only as a rough first comparison, it helps to narrow the field of choices. Having chosen beryllium, we move on to the more accurate methods of structural comparison.

THE PROPERTIES OF BERYLLIUM

A list of properties that determine the structural worth of a metal should include mechanical properties, cost, availability, and whatever other factors that may

influence its usage. Most of these properties (strength, future price, future supply, etc.) are uncertain for beryllium, and the listing below should be considered only tentative.

The strength and modulus of elasticity of beryllium at elevated temperatures are the highest values exhibited by a pressed-powder extruded beryllium produced by the Brush Beryllium Company in 1955. It should be noted that considerable variation in strength is typical of the metal because of its sensitivity to the method of production. The remainder of the data come from reference 3.

Mechanical Properties

Density		0.066	lb./in.^{3}
Modulus of elasticity	70°F.	44×10^6	lb./in.^{2}
	600°F.	43×10^6	lb./in.^{2}
	1,200°F.	26×10^6	lb./in.^{2}
Yield tensile strength, 0.2 per cent offset	70°F.	95,000	lb./in.^{2}
	600°F.	65,000	lb./in.^{2}
	1,200°F.	20,000	lb./in.^{2}
Ultimate tensile strength	70°F.	125,000	lb./in.^{2}
	600°F.	85,000	lb./in.^{2}
	1,200°F.	31,000	lb./in.^{2}
Elongation, as hot-pressed	70°F.	1–5	per cent
	400°F.	8–16	per cent
	800°F.	16–34	per cent
	1,200°F.	10–14	per cent
Specific heat	70°F.	0.46	B.t.u./lb./°F.
	1,200°F.	0.67	B.t.u./lb./°F.
Thermal conductivity	70°F.	87	[(B.t.u./hour)/ft.^{2}]/-°F./ft.
	1,200°F.	65	[(B.t.u./hour)/ft.^{2}]/-°F./ft.
Coefficient of thermal expansion	70°F.	6.4×10^{-6}	in./in./°F.
	1,200°F.	12.4×10^{-6}	in./in./°F.
Corrosion resistance to air		comparable to titanium	
Corrosion resistance to salt water		comparable to aluminum	

The continuing growth of the strength of metals in general within the past few years has been paralleled by the improvement in the strength of beryllium in the last decade (see, for example, reference 3, p. 231). This trend has caused much speculation that future alloys of beryllium may have higher strengths than the best present metal. On the other hand, in predicting the elongation of the metal in the future, it is uncertain whether the elongations obtained at present can be significantly improved.

Cost and Availability

Powdered beryllium metal presently costs about $100/lb. Manual ore-recovery techniques and low-volume ore reduction of separate batches are the primary contributors to this cost. Economists have estimated that if continuous production techniques were warranted and applicable to beryllium, significant quantities of cross-rolled sheets might still cost about $100/lb. This cost was estimated for a time period subsequent to an assumed development program analogous to the effort that went into titanium development.

The main source of beryllium at present is the mineral beryl. One deposit in this country has been estimated to contain enough beryl for 8 million lbs. of beryllium as recovered by present techniques (reference 3, p. 7). Because of the manual labor costs, the beryllium industry has found it more economical to use foreign than domestic sources of beryl. Should a great demand arise for beryllium in structural forms, future availability still remains in question. It has been argued, on the other hand, that present estimates of beryl sources may be conservative in the light of future knowledge of ore discovery and recovery. This suggests that there may be enough beryllium to warrant limited use in aircraft structures.

Toxicity

Beryllium is probably the most toxic of the elements. Beryllium and its compounds, when they are in the finely divided form, can cause acute lung irritations and various skin reactions. Beryllium is somewhat more toxic than lead on an equal-weight basis. As with lead, massive forms of beryllium are, on the other hand, almost harmless since not enough metal rubs off to be of any consequence. Therefore, structural shapes can be safely manipulated by the unprotected hand, while grinding and machining must be performed under ventilated enclosures.

Once the problem of toxicity was recognized by industry, health-hazard controls were developed and used successfully. The metal is produced today with a safety record comparable to that of a nonhazardous industry. It has been estimated that protection against toxicity would contribute about $10/lb. to the cost of beryllium sheet, with perhaps an additional expenditure of $10/lb. for processing structural shapes into finished structures.

Structural Evaluation of Beryllium

Beryllium was proposed for aircraft structures as early as 1935[4] and has been proposed with increasing frequency since then (reference 3, p. 22). It is only recently, though, that enough data have been accumulated about beryllium to permit a more comprehensive structural evaluation. So far in this study, beryllium has been studied only on the basis of its elastic properties. Now we will examine its inelastic properties, using the best beryllium produced today as a tentative example of what a future grade of the metal may afford.

Beryllium is compared with aluminum 7178S-T6, 17-7 PH steel, and 6Al-4Va titanium alloy. The comparison distinguishes between structural elements designed for tensile loads and elements designed for compressive buckling loads and is carried out for structures operating over a range of temperatures. It is assumed that beryllium is available in a sufficiently ductile form and, as mentioned before, that the best beryllium of today is representative of the metal available in the future.

Tension Elements

When tension criteria design portions of an airplane structure, it is customary to use the ratio of the density to the ultimate tensile strength to compare

weights of structures made of various materials. This ratio, when divided by the ratio for aluminum at 70°F., represents the relative weight of tension elements. It is plotted against temperature in Fig. 3 for conventional metals and for beryllium. Beryllium tension structures appear lighter by a considerable margin. Comparison by this method omits consideration of fatigue and creep properties of the individual materials; but since few fatigue and creep data exist for beryllium, this method offers the best comparison with the information available at present.

Elements Designed by Buckling Criteria

The methods of optimum design provide the means for comparing materials when used in thin-walled structures designed by buckling criteria.[5] The sheet-stiffener panel is chosen as the basis of comparison since it behaves similarly to other thin-walled structures loaded in compression, shear, or bending.

The procedure of reference 5 starts from the stress-strain curves of materials (shown in Fig. 4) and concludes with the equivalent allowable stress versus structural index curves shown in Fig. 5. The equivalent allowable stress is usually defined as the buckling stress multiplied by the ratio of the density of aluminum to the density of material. The structural index is a design parameter that relates the load that a structure must carry and the distance over which the load is transmitted.[1] For panels, the index can be defined as the distributed load q(lb./in.) divided by the panel length L_0(in.).

In Fig. 5 the elastic lines are shown to point out the importance of including the inelastic behavior of metals in a structural evaluation. For example, magnesium appeared superior to aluminum in Fig. 1 based on its elastic properties. From Fig. 5 it can be seen that this superiority is retained only up to an index of about 150 psi; beyond this point the inelastic behavior of magnesium causes it to be inferior to aluminum.

The curves of structural index versus allowable stress of Fig. 5 can be determined at different temperatures, but to simplify the evaluation an index of 300 psi (typical of a modern airplane) may be chosen as a particular example. Values of equivalent allowable stress at this structural index can then be used to calculate relative weights of panels of different materials at various temperatures. Fig. 6 shows how the relative weights vary with temperature. Beryllium compression panels appear to be less than half as light as panels made of conventional materials at all temperatures.

Structural Weight of Airplanes

The amount of structure which is designed by buckling in an airplane is usually greater than the amount designed by tension. A recent estimate has indicated that about two thirds of the weight of the structure of a modern commercial transport is designed to resist buckling. The proportions of elements designed by tension and by buckling criteria are not too important when one is considering beryllium since both types of

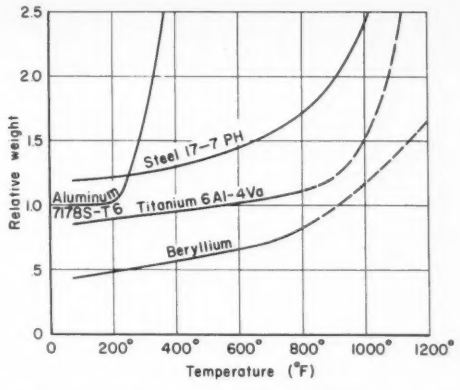


FIG. 3. Relative weight of tension elements at various temperatures.

beryllium structural element weigh about 0.4 as much as aluminum ones at room temperature. (See Figs. 5 and 6.) However, the usual definition of an aircraft structure includes many items that may not be redesigned into another material such as beryllium. Although beryllium could be substituted hypothetically for other metals in about four fifths of the structure of a modern transport, there still remains about one fifth of the weight where beryllium could not be utilized. Using these ratios of 4:5 and 1:5, it can be concluded that a complete transport airplane structure would weigh about (4:5) (0.4) + (1:5) (1) = 0.52 as much as the aluminum one. A weight reduction of almost one half is significant for aircraft structures, and a further example is shown below to illustrate what such weight reductions can do to the performance of the airplane.

An Example of Beryllium Usage in a Hypothetical Transport Airplane

A turbojet-powered transport airplane, capable of delivering a pay load of 35,000 lbs. at a cruising speed of Mach 0.85, will be the example used to illustrate the effect of hypothetical beryllium usage in aircraft. Such an airplane is similar in capability to some jet transports presently being designed for commercial use. The example is hypothetical in that the beryllium airplanes are assumed to be made of a metal with the highest strength obtained in the laboratory at present and with elongation and other properties sufficient for structural use but not yet achieved today.

The characteristics of the aluminum aircraft are from Tables 58 and 59 of reference 6. The main features of the families of transports of this study are

Design pay load	35,000 lb.
Fuselage diameter	14.5 ft.
Fuselage length	125 ft.
Design cruising speed	$M = 0.85$
Initial cruise altitude	40,000 ft.
Wing sweepback angle	30°

Wing areas, gross take-off weights, and other design parameters are varied to obtain different design ranges. The beryllium and aluminum aircraft being compared are identical as to power plant, pay load, speed, altitude,

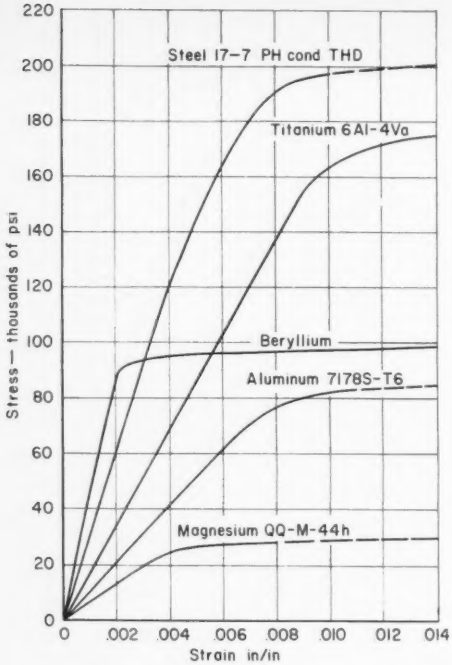


FIG. 4. Compressive stress-strain curves for various materials at room temperature.

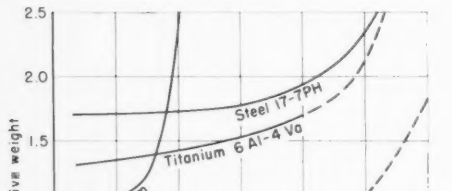


FIG. 6. Relative weight of sheet-stiffener panels at various temperatures ($q/L_0 = 300$ psi).

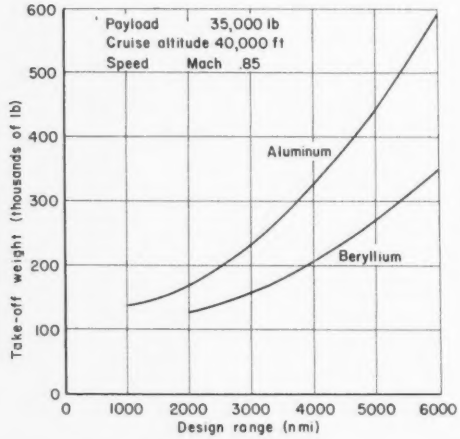


FIG. 7. Take-off weight vs. design range for beryllium and aluminum transport airplanes.

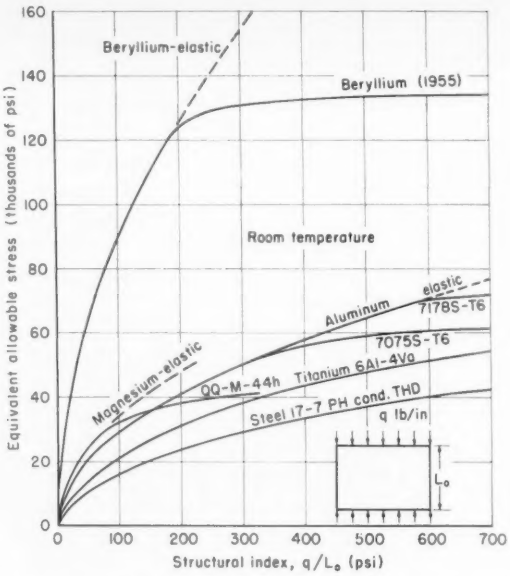


FIG. 5. Comparison of metals used as sheet-stiffener panels.

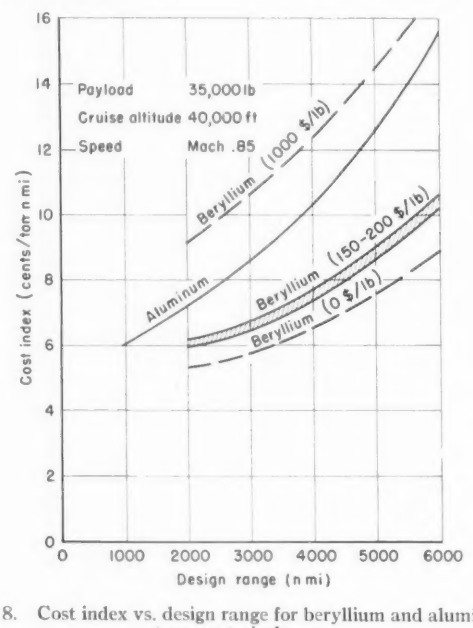


FIG. 8. Cost index vs. design range for beryllium and aluminum transport airplanes.

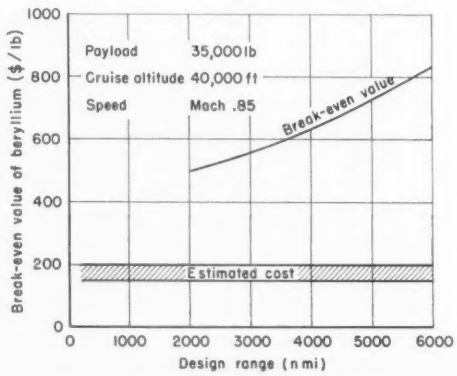


FIG. 9. Break-even value of beryllium vs. range in transport airplanes.

and overall dimensions; they differ only in range capability, fuel weight, and structural design and material.

The structural weight of the beryllium transports is assumed to be 0.52 times the corresponding weight of an aluminum airplane. The structural weight reduction resulting from the theoretical beryllium design permits an increase in fuel weight equal to almost half the aluminum structural weight. This additional fuel extends the range of a beryllium transport beyond that of the aluminum transport of equal take-off weight. This effect on range extension is shown in Fig. 7, using the procedures outlined in reference 6.

A significant extension of range appears to result from using beryllium, but it should be cautioned that it is obtained only by using a hypothetical material of extremely high initial cost. The role of initial cost of the structural material can be evaluated also by the methods of reference 6 by comparing the operating cost index* of beryllium and aluminum transports. Cost indices are shown in Fig. 8 for aluminum and beryllium transports where three cost levels per installed pound of beryllium are assumed—0 $/lb., 150–200 $/lb., and 1,000 $/lb. Of the three, the cost of 150–200 $/lb. is a rough estimate of the unit cost of a finished beryllium structure of the future, after an intensive (and extensive) development program.

It can be seen from Fig. 8 that beryllium transports are more economical only if the installed unit cost of the structure falls below a certain level. The price level of beryllium air frames at which aluminum and beryllium transports are of equal capabilities and operating cost determines a break-even point. This break-even value of beryllium can be read directly by interpolation from Fig. 8 and has been plotted in Fig. 9. It can be seen that the value of beryllium is well above the estimated future cost, and, as one would expect, the value increases with the difficulty of the required capability (range).

Discussion

Deterrents to Beryllium Usage

So far, beryllium has been shown to have many advantages and disadvantages when it is considered for structural applications. A review of the deterrents and their importance in the light of this study can now be made. The four primary deterrents are high cost, scarcity, toxicity, and brittleness.

An installed cost for beryllium of 150–200 $/lb. is indeed high compared with that for aluminum (usually priced at 20–40 $/lb. installed). However, because of the increased capability of hypothetical beryllium airplanes, it seems that its value in an airplane is higher than its cost (Fig. 9).

At present price levels, beryllium structural shapes are practically unavailable. This scarcity is the composite result of the absence of a demand for the product at higher prices, ignorance of the available resources, competition with other users of the metal, uncertainty as to mechanical properties, etc. On the other hand, the few existing estimates of beryl deposits give indications that sufficient quantities could be produced (under the proper price incentives) to be of interest to structural designers.

Toxicity is a deterrent primarily because it is an undesirable characteristic of beryllium. It will appear in the form of additional expense in the manufacture of the structures and in special handling precautions for the finished air frame.

Brittleness looms as the major deterrent in the present beryllium state-of-the-art. It is uncertain whether the ductility of 1957 beryllium can be significantly improved, and it is not clear that this beryllium will ever qualify as an acceptable structural material. The importance of the brittleness problem cannot be overemphasized since none of the advantages of beryllium could be utilized without a solution to this deterrent.

A sizable research effort in the brittleness problem which has been carried on by the Atomic Energy Commission for a number of years has resulted in a vastly improved understanding of the problem. This effort, part of a larger program to make beryllium available for nuclear purposes, is summarized in reference 3.

Brittleness: The Most Serious Deterrent

The basic beryllium crystal under tension loads exhibits a fair amount of ductility in some directions but behaves in a brittle manner in other directions. This apparently inherent property of the crystal results in the low values for elongation of beryllium metal. Some success has been achieved in raising the ductility by using powder-metallurgy techniques: the powdered metal is compacted, extruded, and cross-rolled into sheets. These sheets have 30 to 40 per cent elongation under uniaxial loading in the plane of rolling and unknown elongation perpendicular to it (reference 3, p. 425). There has been no evaluation of this material for application to aircraft structures.

A more desirable solution of the brittleness problem would be to increase the elongation in the presently brittle directions of the crystals themselves, although there are no indications that this can be accomplished. Even though this solution has a low probability of success, it is appealing because it would simplify the production and improve the reliability of structural shapes.

Conclusions

It can be concluded that beryllium would be an extremely desirable structural material if certain deterrents to its use could be minimized. Of these deterrents, high cost, scarcity, and toxicity are of an economic nature and appear reducible by the application of the proper economic incentives. Brittleness, on the other hand, seems inherent in the physical nature of the metal, and a better understanding of this problem is

(*Continued on page 82*)

* The cost index is defined as the cost of transporting a ton of pay load over one nautical mile. It accounts for crew costs, fuel and oil costs, air-frame plus power-plant depreciation, and maintenance expenditures.

A. D. Topping*
Goodyear Aircraft Corporation

Behavior of Materials Under Combined Stresses in Pressurized Structures

Taking a recent paper by Zaustin as a point of departure, the author suggests two approaches to minimum-weight design of pressurized aircraft structures: The first is based on experience with rock, the second on experience with fabric.

Introduction

The importance of combined stresses in pressurized structures has been pointed out by M. Zaustin.[1] The present discussion attempts to correlate experience with such diverse materials as rock and fabric with structural problems in the design of pressurized aircraft.

The chief points made in reference 1 are

(1) Materials tend to be brittle in the presence of biaxial tensile stresses, which are inescapable in pressurized structures.

(2) Brittleness in aircraft structures is undesirable for a number of important reasons. (The Comet disasters were due to the brittleness under combined stress of nominally ductile metals.)

(3) The usual theories of strength are inadequate because they do not provide for ductility.

(4) Tensile strength is not a fundamental property but a composite of "cohesive" and "shearing" strengths, which unfortunately are not defined. The first of these is said to be obtainable from tests of notched cylindrical tensile specimens and the second from torsion testing of thin tubes.

Octahedral Stress Components

To begin with fundamentals, the brittleness or ductility of a material is not a basic property peculiar to it but depends on such physical conditions as temperature, strain rate, and volumetric stress. Here it is the last which seems most important.

The basic components of stress may be regarded as shearing stress and volumetric stress—i.e., octahedral shearing and octahedral normal (hydrostatic) stresses, respectively. In elasticity theory, the deformation constants corresponding to these stresses are the bulk modulus and the modulus of rigidity rather than the tensile modulus and Poisson's ratio. Volumetric strains (in nonporous materials) are always elastic; the octahedral shearing strains only may be partially plastic.[2, 3] The greater the plastic octahedral shearing strains before separation (rupture) occurs, the more ductile the material. Ductility is a function of octahedral normal stress; Balsley[4] obtained tensile strains of 25 per cent in marble under 8,000 atmospheres of pressure. Conversely, the greater the octahedral normal stress (tension positive), the more brittle the material. Incidentally, since the octahedral normal stress in a uniaxial test is exactly one third the axial stress, an increase in the tensile strength of a material should tend to be accompanied by a decrease in uniaxial ductility, which is in general consistent with observation.

In a right-angled coordinate system with coordinates σ_1, σ_2, σ_3, the volumetric (octahedral normal) stress axis runs through the all-tension and all-compression octants making equal angles with the principal axes. The brittleness of a given material might be represented by a point on this axis defining the hydrostatic stress at which the material is neither ductile nor brittle. Unfortunately, "brittle" and "ductile" are mathematically indefinite terms until some arbitrary boundary between them has been established, such as that plastic octahedral shearing strains at rupture if more than, say, 0.5 per cent indicate ductility and if less indicate brittleness. When such a point has been established for each of a group of materials of similar microstructure, it may be expected that the behavior of all will differ qualitatively only according to their position along the hydrostatic (brittle-ductile) axis.

* Engineer Specialist (Stress).

Criteria of Strength

The distortion energy or octahedral shear theory [5, 6, 7] and maximum shear theories of strength can be represented in the stress-space system described above by a cylinder and its inscribed hexagon, respectively, having the volumetric stress axis as an axis of symmetry. These theories have been confirmed experimentally for yielding of ducitile metals but are clearly inadequate (as Zaustin says) for fracture since, although a hydrostatic tension cannot produce yielding, it can produce fracture. The surface which represents fracture must therefore be closed at the tension end. On the other hand, a hydrostatic pressure produces neither yielding nor fracture in a nonporous material so that the surface must be open at the compression end. The best known theory satisfying these requirements is the Mohr theory; another has been suggested by Schleicher[8] and Nadai[5, 6] and bears the same relation to the Mohr theory that the octahedral shear theory does to the maximum shear theory, the radius of the Schleicher-Nadai circle in which the Mohr hexagon is inscribed being a function of the octahedral normal stress instead of constant. Both theories were intended for materials ordinarily considered brittle, but a study[9] of the results of triaxial tests on marble indicates that they are most accurate for yielding at pressures under which the rock behaves in a ductile manner. Neither has been confirmed by experiment for rupture.[9, 10]

Reference 11 points out that a stress criterion of rupture is not satisfactory since (1) the plane of cleavage during rupture can be subjected to compressive stress only (macroscopically) and (2) for a non-strain-hardening ductile material it would imply that fracture occurred simultaneously with yielding. Freudenthal[3] has shown from microstructural considerations that both yielding and fracture must be governed by energy criteria; yet a material which has a flat-topped stress-strain curve absorbs no energy in that range, the input energy being dissipated into heat. What happens, evidently, is that the energy absorption capacity of the material decreases as it is strained until this capacity is less than the stored energy, when rupture occurs (Fig. 1). By reducing the energy criterion of failure to a strain criterion instead of a stress criterion, then rupture can be described as a function of the ductility of the material, the desirability of which is indicated by reference 1.

Since the volumetric strain is elastic, the criterion can be consistently expressed either as

$$\gamma_f = f(\epsilon, \theta) \text{ or } \gamma_f = f(\sigma, \theta) \qquad (1)$$

where γ_f is the octahedral shearing strain at rupture, ϵ is the volumetric strain, σ is the octahedral normal stress, and θ is the angle between the octahedral shear vector and a reference axis in the octahedral plane.[9] Specific forms of this equation in terms of certain experimental constants can be established analogous to various stress criteria of strength. For example, the criterion of failure may be found to be independent of θ for some materials, as it is for yielding of metals equally strong in tension and compression according to the distortion energy theory.

Discussion

Any program of testing intended to arrive at a quantitative measure of ductility, then, should aim at correlation of rupture strains with hydrostatic stress or strain. In applying the results, calculated octahedral shearing strains in the structural part can be compared with a corresponding empirical criterion obtained from analysis of the test data.

This approach should be more fruitful in the long run than the approach proposed by Zaustin[1] (see item 4 above), which, while it is far from clear just what are the "tangential" and "normal" stresses he speaks of,* appears to be based on a two-dimensional conception of the brittleness-stress relation. For instance, the state of stress at the root of the notch (circumferential groove) in his control specimen is not only nonhomogeneous but triaxial, rather than biaxial as in the intended application of thin-walled pressure vessels; and the third stress component can make an enormous difference. For example, the yield strength of a ductile metal is little affected by the addition of a second tensile stress of equal magnitude, but a third tensile stress causes it to increase toward infinity as the third tension approaches the other two in magnitude. A two-dimensional analysis is often an oversimplification inadequate to explain the behavior of physical materials, which are indubitably three-dimensional. Further, quantitative interpretation of a brittle fracture in a notched tensile specimen obtained by lowering the temperature or increasing the strain rate will probably be less easy than reference 1 implies, especially since the transition from ductility to brittleness is not really abrupt. The approach suggested in reference 1 may nevertheless be useful as a stop-gap since more basic information may prove difficult to obtain.

* If they were octahedral stresses, his τ/σ ratios in simple tension and in a pressure vessel would be 1.414 and 0.817. For some reason, he has apparently divided both ratios by 2.83.

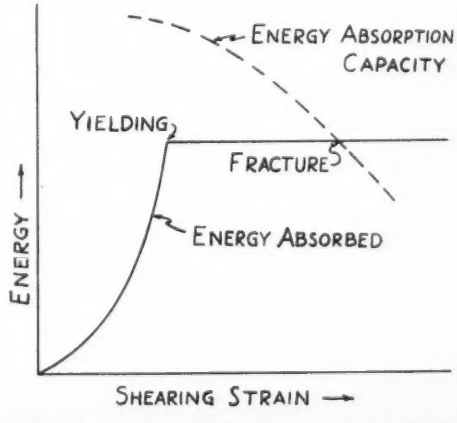


Fig. 1. Fracture in a non-strain-hardening material.

Investigation of the strength of aircraft structural materials in terms of strains as a function of hydrostatic stress will furnish the kind of information necessary to design pressurized structures from homogeneous materials. It will not, however, suggest any measures to improve safety except reducing working stresses or going to more ductile materials—which generally means to materials having lower strength-weight ratios.

It is, of course, possible to reduce areas of high stress concentration by refinement of the design and to inhibit the spread of cracks by stiffeners and doublers, but such measures are essentially palliative rather than basic solutions.

Now although pressurization has been just one more weight-booster in conventional aircraft structures, pressurization has been employed to *solve* the primary structural problem in nonrigid airships for decades, and structural pressurization is now finding new aircraft applications—for example, in the British pneumatic wing and in Goodyear's pneumatic airplane for basic strength, and in high-speed aircraft to minimize skin thicknesses to reduce thermal stresses. In view of the fact that the materials used—fabrics—have usable tensile strength-weight ratios that are only mediocre and have no compressive strength at all, this may seem a little surprising. The principle, of course, is that because the compressive strength of thin sheet is so low anyway, half the tensile strength can be sacrificed by prestressing with gas pressure to yield a net gain in the overall strength-weight ratio of the structure which in some instances may be astonishing. But what about the biaxial-tension brittleness problem?

Fabric Strength and Structure

Failure of fabrics under biaxial stress is called tearing; the same terminology is used for films and could as well be used for sheet metals. It is essentially the same phenomenon discussed by Zaustin.[1] Tear strength has been a familiar problem in the design of nonrigid airship envelopes and fabric structures for half a century. The relation between ductility and tear strength is not generally understood, however, perhaps because the common ground between fabric and sheet metals has not been clearly pointed out. It has been a truism, however, that fabrics have much higher tear strength than films, though there seems to be little quantitative information on the point. The reason for this becomes clear when it is considered that fabrics are made up of elements which can be stressed only uniaxially even when the fabric as a whole is under biaxial stress, while in films the elements are stressed biaxially. At a point of stress concentration, then, the fabric can yield and redistribute the load, while the film becomes brittle under the stress and cracks. The stress concentration at the root of the crack causes it to spread rapidly, whereas in the fabric, should a tear start, the concentration is relieved by the uniaxial ductility of the individual threads. On a quite different scale, this corresponds to the inhibiting effect of stiffeners on the tearing of sheet metal observed by Sorenson.[12] It is worth noting that the uniaxial ductility of cotton, nylon, Fortisan, Dacron, and Orlon fibers, which are the commonest materials currently used in structural fabrics, is not great compared to most metals, although the strain at rupture may be as much as 30 or 40 per cent, since much of this strain is recoverable and hence elastic, albeit nonlinear. However, a measure of stress relief is also provided in most fabrics by the crimp which is a consequence of the weaving process.

On the other hand, fabrics require two sets of threads to resist stresses in the principal directions, and in a pressure vessel they also need a coating of neoprene or rubber (or similar impermeable material)—weighing (in airship experience) about the same as the basic cloth—in order to be able to hold a fluid. Since this means that the strength-weight ratio of the fabric is only one fourth that of the yarns, which might be expected to compare with that of a film of the same material, the question is whether the gain in ductility offsets this apparent weight penalty. Actually, the strength-weight ratio of films may be about the same as that of the corresponding fabric, judging from a comparison of Mylar with an experimental Dacron-neoprene fabric manufactured at The Goodyear Tire and Rubber Co., Inc. (Mylar and Dacron are chemically the same material.) Why this should be so is not now understood.

Fabrics, Films, and Metals

Since there have been one or two historical instances of film or sheet metal replacing fabric in pressurized aircraft with apparent success, though none as yet of fabrics replacing metals, it is pertinent to examine these instances to see how far they confirm or refute the propositions regarding tear strength which have been put forward.

One was the "metal-clad" airship, ZMC-2, whose envelope was 0.0095 in. 17S Alclad sheet. (This had been found to be the minimum practical gage.) Although only one such airship was ever built, it was regarded by its designers as a success,[13, 14, 15] and no difficulty with tear strength seems to have been encountered. This need not surprise us in view of the limited service of the craft and the high ductility of 17S Alclad, especially when we learn that the skin had a minimum factor of safety of 5.0.[14] This safety factor is comparable to that used in current fabric envelopes for nonrigid airships, where, however, it is called for by the creep-rupture characteristics of fabrics, uncertainties peculiar to fabric regarding stress distributions, and the effects of humidity and weathering—none of which have any importance in metal aircraft except the last, as corrosion. Conventional heavier-than-air craft are, of course, usually designed with a factor of safety of 1.5; but ordinarily the margin between pressure stresses and ultimate tensile strength has been much larger—especially since the Comet I.

Another type of pressure vessel in which weight is important is the high-altitude balloon, which is made of

polyethylene film. Its success in this application is probably due to the 200 to 800 per cent elongations it can undergo before failure.[16]

All these observations suggest that the peculiarity of fabrics which enables them to remain competitive with films and sheet metals in spite of their inherent disadvantages is the uniaxial ductility associated with their nonhomogeneous structure. (Actually, there is a second factor—the ability of inflated fabric structures to recover their original shapes and strength after buckling; but this seems irrelevant to a discussion of tear strength.) Fiberglass laminates have a similar nonhomogeneous structure, but unfortunately glass cloth has so little uniaxial ductility that no important advantage can be expected. We are led, therefore, to envision such things as metal cloths and reinforced sheet—e.g., aluminum reinforced by steel wires—as possible optimum solutions to the pressurized structure problem. The structural desirability of reinforcing relatively brittle castings with ductile (uniaxially stressed) rods is similarly suggested by the success of reinforced concrete in the civil engineering field.

In the optimum design of such a bimetallic material, the elongations of the biaxially stressed matrix must be matched with the uniaxial elongations of the reinforcement so that the matrix should have the lower modulus, although the rupture strain of the reinforcement should always be greater than that of the biaxially stressed matrix. Among other technical obstacles to the development of reinforced metals, then, is a need for the same rupture strain data as in the design of homogeneous pressurized structures.

Conclusions

The design of pressurized aircraft brings the structures engineer face to face with the phenomenon of brittleness due to the presence of hydrostatic tension. There are three approaches toward the solution of the minimum-weight design problem:

(1) Increasing basic knowledge by quantitative determination of rupture strains as a function of hydrostatic stress for each of the various structural materials.

(2) Refinement of current design practices.

(3) Introduction of nonhomogeneous structural materials like fabric or reinforced metals.

Of these approaches, only the second, which is essentially a palliative, has so far been taken. Zaustin[1] has suggested methods of increasing basic knowledge, but they do not appear to offer more than a stop-gap solution. The third approach has not, so far, been given serious consideration outside the lighter-than-air field.

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A graphical method has been derived in this analysis to solve directly the heat-balance equation, thus eliminating the customary trial-and-error calculations previously performed.

Direct Solution of the Heat-Balance Equation for Thermal Anti-Icing Systems

(1) Symbols

a	= width of flow area in corrugations, in.
b	= perimeter of corrugation, in.
c	= portion of corrugation in direct contact with outside skin, in.
d	= portion of corrugation containing stagnant air, in.
c_P	= specific heat of air at constant pressure, 0.24 B.t.u./lb., °F.
e_0	= saturation vapor pressure of water at t_0, in. Hg
e_s	= saturation vapor pressure of water at t_s, in. Hg
h	= air film convective heat-transfer coefficient, B.t.u./hour, ft.², °F.
H	= partial rate of heat transfer, B.t.u./hour, ft.²
K	= surface-wetness fraction
k_j	= joint conductance, 55 B.t u./hour, °F., ft.²
L	= distance between vertical scales of nomographs, in.
M_{ev}	= rate of evaporation of water, lbs./hour, ft.²
M_w	= rate of interception of water, lbs./hour, ft.²
m	= scale factor [defined in Section (8)]
P	= static pressure, in. Hg
S	= height of vertical scales of nomographs, in.
q	= total rate of heat transfer, B.t.u./hour, ft.²
t	= temperature, °F.
V	= velocity, ft./sec.
A, B, C, Z	= heat-balance parameters [defined in Section (6)]

Subscripts

0	= undisturbed ambient stream
a	= external air
ap	= internal hot gas
c	= corrugation skin
l	= local
s	= outside skin
w	= water

(2) Introduction

In the design of thermal anti-icing systems, the number of variables present necessitate tedious trial-and-error calculations for the solution of the heat requirements for the evaporation of the impinged water. Numerous methods have been developed for the solution of the heat-balance equation in the form of graphical and semigraphical methods, which eliminate some of the laborious calculations of the trial-and-error method.[1] The use of an electrical analogy has been investigated, and, with the aid of analog computers, the time factor has been greatly reduced.[3, 4] The disadvantage of the solution of the problem with analog computers is in the high cost of procuring such equipment, if not available, and in the time consumed in setting the equipment to solve the problem. There is also the complication of continuously feeding the apparatus with variables, etc. The method presented in this report solves the equation directly with the help of nomographs.

(3) Heat Transferred From the Air in Corrugated Passage to Wing Surface

For the purpose of illustration, assume a leading-edge duct construction as shown in Fig. 1 where a = 0.693 in., b = 1.00 in., c = 0.42 in., and $a + c + 2d$ = 1.20 in. If H_1 = rate of heat transfer from air in corrugations direct to wing surface in B.t.u./hour, ft.², then

$$H_1 = h_{ap}[a/(a + c + 2d)]\,(t_{ap} - t_s) \qquad (1)$$

Similarly, if H_2 = rate of heat transfer from the air in the passages to the corrugated inner skin of wing surfaces in B.t.u./hour, ft.², then

$$H_2 = h_{ap}[b/(a + c + 2d)]\,(t_{ap} - t_c) \qquad (2)$$

also

$$H_2 = k_j[c/(a + c + 2d)]\,(t_c - t_s) \qquad (3)$$

* Thermodynamics Engineer.

where k_j = joint conductance = 55 B.t.u./hour, °F., ft.^{2}.[6] Note that along d the amount of heat transferred can be neglected since the air is stagnant.

Solving Eqs. (2) and (3) for t_c (in °F.) and substituting the values of the corrugation geometry,

$$t_c = (h_{ap} \times t_{ap} + 23.1 \times t_s)/(23.1 + h_{ap}) \quad (4)$$

Substituting Eq. (4) into Eq. (2) and adding Eqs. (1) and (2), $H_1 + H_2 = q$, total rate of heat transfer to outer wing surface (in B.t.u./hour, ft.^{2}), or

$$q = [h_{ap}(13.05 + 0.231h_{ap})/(9.24 + 0.4h_{ap})] \times (t_{ap} - t_s) \quad (5)$$

In Eq. (5) all the variables are known except the equilibrium temperature of the skin t_s.

Eq. (5) is plotted in Fig. 2 to simplify the calculations. For a gap geometry other than the one illustrated, the corresponding values of a, b, c, and d would be substituted in Eqs. (1), (2), and (3) and the constants of Eq. (5) thus determined.

(4) External Heat Transfer

During flight in icing conditions, a heated wing is cooled by convection, by evaporation of the water on the surface, and, in the region of water-drop impingement, by the water striking the wing.

The heat transfer from the surface exposed to icing and heated above 32°F. is expressed by the following equation (rearranged from reference 1):

$$q = \{(t_s - t_0)\,[1 + (M_w/h_a)] - (V_0^2/5 \times 10^4)\,[3.55 + (M_w/h_a)] + 2760K[(e_s/P_l) - (e_0/P_0)] + 19.9[1 - (P_l/P_0)]\}h_a \quad (6)$$

In Eq. (6) all the variables are known for every wing station except the equilibrium temperature, t_s, and e_s, the partial pressure of the water vapor corresponding to t_s. In the past, the right-hand members of Eqs. (5) and (6) were equated to represent the total heat balance, and various values of t_s and e_s were then substituted until the equation balanced.

(5) Relation of Vapor Pressure With Temperature

A relation between the vapor pressure and temperature has been derived by the author from values of the above physical properties of water vapor:

$$e_s = 2.2 \times 10^{-8}(t_s)^{3.9} + 5 \times 10^{-3}(t_s) + 0.024 \quad (7)$$

The above relation has been checked for 30°F., 100°F., and 130°F., resulting in a discrepancy of 6 per cent, 0.5 per cent, and 0.3 per cent, respectively.

(6) Direct Solution of the Equilibrium Surface Temperature

Substituting Eq. (7) into Eq. (6) and equating Eqs. (5) and (6):

$$(t_s)^{3.9}6072 \times 10^{-8}\frac{K}{P_l} + t_s\left[1 + \frac{M_w}{h_a} + \frac{K}{P_l}13.8 + \frac{h_{ap}(13.05 + 0.231h_{ap})}{h_a(9.24 + 4h_{ap})}\right] = \frac{h_{ap}(13.05 + 0.231h_{ap})}{h_a(9.24 + 0.4h_{ap})} \times t_{ap} + t_0\left(1 + \frac{M_w}{h_a}\right) + \left(\frac{V_0^2}{5 \times 10^4}\right)\left(\frac{M_w}{h_a}\right) + K\frac{e_0}{P_0}2760 - K\frac{66.4}{P_l} + 19.9\frac{P_l}{P_0} + 7.1 \times 10^{-5}\,V_0^2 - 19.9$$

the above equation can be written in the form

$$A(t_s)^{3.9} + B(t_s) = C \quad (8)$$

where

$$A = (K/P_l)6072 \times 10^{-8}$$
$$B = 1 + (M_w/h_a) + (K/P_l)13.8 + Z$$
$$Z = h_{ap}(13.05 + 0.231h_{ap})/h_a(9.24 + 0.4h_{ap})$$
$$C = Z(t_{ap}) + t_0[1 + (M_w/h_a)] + (V_0^2/5 \times 10^4) \times (M_w/h_a) + K(e_0/P_0)2760 - K(66.4/P_l) + 19.9(P_l/P_0) + 7.1 \times 10^{-5}(V_0)^2 - 19.9$$

The terms A, B, C, and Z can be solved for any flight condition and for every wing station, independent of the skin temperature, and are considerably simplified downstream of the impingement area since M_w will then be zero. Z can be plotted graphically (see Fig. 3) to simplify the calculations.

Note that Z is the only term in the expressions denoted by B and C that is related to the physical shape and size of the corrugations used. Thus, to obtain a value of B and C for any other type of corrugation, only a new value of Z need be calculated, all other terms being constant. This is done by employing the numerical constants of Eq. (5) which are identical to those of Z.

Having thus calculated A, B, and C, t_s is found directly from Fig. 4 or Fig. 5. For example, let $B/A = 4.8 \times 10^{-6}$ and $C/A = 7.0 \times 10^{-8}$ in Fig. 5 and join B/A and C/A to obtain $t_s = 119.3$°F. Knowing t_s, the heat flow q to the outer skin is obtained from Eq. (5) or Fig. 2, and, therefore, the heat-balance equation is solved.

The error introduced by using Eq. (7) to determine the equilibrium skin temperature has been checked for the temperatures of 30°F., 100°F., and 130°F. and was found to be 4 per cent, 0.3 per cent, and 0.3 per cent, respectively.

(7) Calculation of Required Rate of Heated Airflow

The following is a brief description of the standard procedure to be used in obtaining the required airflow rate. Once the equilibrium skin temperature and the heat flow for the first point on the wing are known, the temperature drop of the air in the corrugation at the next chordwise station is assumed to be proportional to the amount of heat previously removed from the airflow. Therefore, an assumption is made for the air

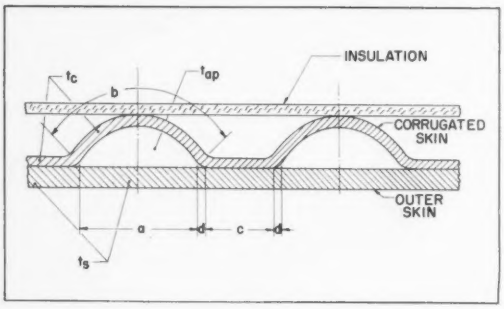


FIG. 1. Typical corrugation section where t_{ap} = corrugation air temperature, t_c = corrugation skin temperature, and t_s = outer skin temperature.

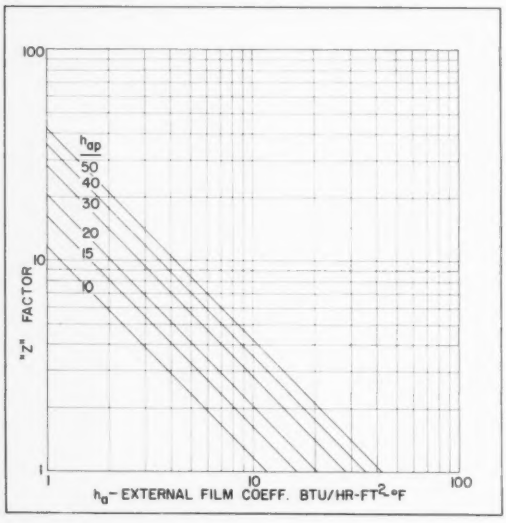


FIG. 3. Plot of Z factor vs. h_a where $Z = h_{ap}\,(13.05 + 0.231h_{ap})/h_a(9.24 + 0.4h_{ap})$ and h_{ap} = internal film coefficient, B.t.u./hour, ft.², °F.

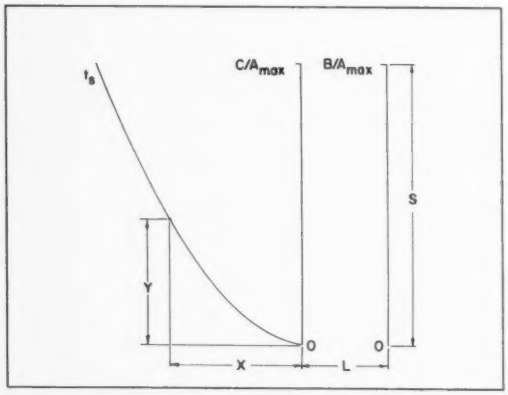


FIG. 6. Elements of construction of nomograph.

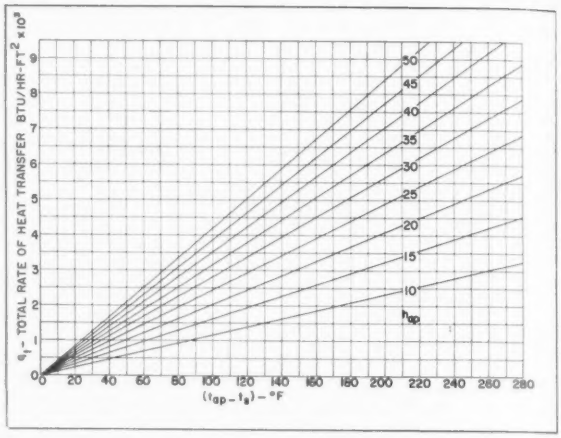
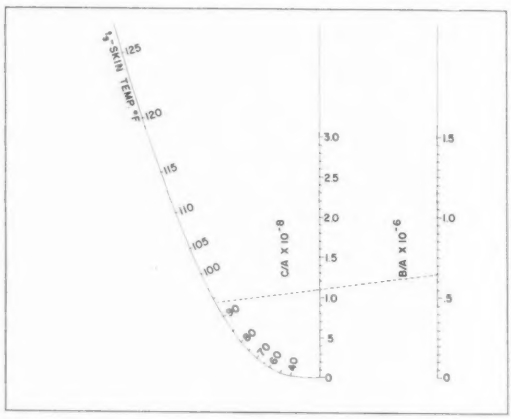


FIG. 2. Plot of q_t vs. $(t_{ap} - t_s)$ where $q_t = [h_{ap}(13.05 + 0.231h_{ap})/(9.24 + 0.4h_{ap})]\,(t_{ap} - t_s)$; t_{ap} = corrugation air temperature, °F.; t_s = skin temperature, °F.; and h_{ap} = internal film coefficient, B.t.u./hour, ft.², °F.



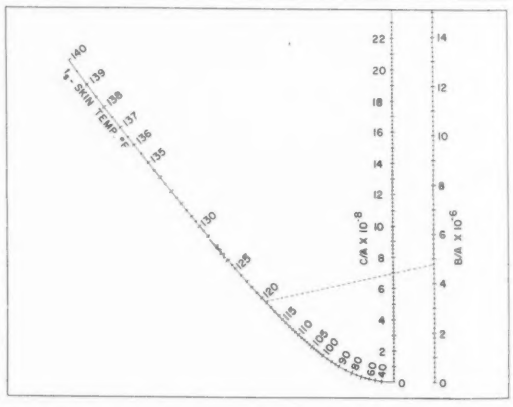


FIG. 4 (*top*), FIG. 5 (*bottom*). Solution of the equation $(t_s)^{3.9} + (B/A)\,(t_s) = C/A$, where A, B, and C are parameters as defined in Section (6).

temperature t_{ap} at the second station. The skin temperature is then calculated for the second station using the same procedure as discussed above. Having thus calculated the skin temperature at the second point, the temperature drop of the air in the corrugation is calculated by equating the heat removed from the air to the average heat flow between the two stations.

If the assumed value of air temperature is found to be correct, the cycle is repeated until all the skin temperatures are known. If the assumed value was incorrect, a new value is assumed close to the calculated value, and the skin temperature is recalculated.

It should be noted that, in repeating the calculation for t_s with a new value of t_{ap}, only the one term of parameter C, $Z(t_{ap})$, is affected. Thus the new value of t_s can be found very rapidly. The rate of evaporation is then calculated using the formula[5]

$$M_{ev} = 2.9 h_a K[(e_s/P_t) - (e_0/P_0)]$$

In cases where the rate of evaporation is larger or smaller than the rate of water catch, the assumed airflow has to be changed accordingly and the calculation repeated by changing only the term Z of the parameters B and C including the internal film coefficient h_{ap}.

(8) Construction of Nomograph (Figs. 4 and 5)

No attempt will be made in this paper to explain the theory of nomographs. Such information can be found in reference 7.

To enable the reader to reproduce Figs. 4 and 5 the mechanics of their construction is given below:

A convenient scale S (see Fig. 6) is chosen and the possible range of values of C/A and B/A estimated, the maximum values being assigned to the top of the scale. m_1 and m_2 are now calculated as follows:

$$m_1 = S/(C/A)_{max}$$

$$m_2 = S/(B/A)_{max}$$

The coordinates of the t_s curve, X and Y are then

$$X = Lm_1(t_s)/[m_1(t_s) + m_2]$$

$$Y = m_1 \times m_2(t_s)^{3.9}/[m_1(t_s) - m_2]$$

where L is the distance between the scales. This nomograph is simply a general solution of the equation

$$(t_s)^{3.9} + (B/A)\,(t_s) = C/A$$

and will therefore apply to any conditions which satisfy the equation.

(9) Conclusion

The direct solution of the complex heat-balance equation of a heated wetted surface eliminates the trial-and-error calculations previously performed, thus saving considerable time in evaluating the thermal requirements for anti-icing. The solution is applicable to any geometrical shape for which the basic variables and ambient conditions are known.

For wings with varying gap geometry, the constants of Eq. (5) and parameter Z can be calculated, and a series of graphs similar to Figs. 2 and 3 may be plotted to facilitate the calculations. In the region near the 0 per cent chord, corrugations are rarely present. For this condition, Z reduces to h_{ap}/h_a, and Eq. (5) becomes $q = h_{ap}(t_{ap} - t_s)$.

When an electric heat source is used instead of hot air, the same procedure is used, utilizing the same equations and nomographs, with the exception that Z equals zero and the term q/h_a is added to parameter C.

The method derived in this analysis can be used for a point-by-point solution along a surface, or for a solution in which primary factors are approximately constant over a surface, and can be conveniently averaged. As previously mentioned, the error in the calculation of water-vapor pressure will introduce errors of 4 per cent, 0.3 per cent, and 0.3 per cent for temperatures of 30°F., 100°F., and 130°F., respectively, in the heat-balance equation.

These errors are negligible, however, compared with the uncertainty and latitude involved in evaluating the basic variables—specifically, the water impingement rate and the external film coefficient.

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Ram Vaswani*
The Ohio State University

The Aircraft Assignment Problem

An analytic linear programing solution illustrating the application of Flood's optimal assignment technique, which is basically simple to apply and can be used routinely by clerical personnel.

Introduction

THE ALLOCATION THEORY has lately been receiving the increasing attention of mathematicians, economists, and management executives.[1] Several techniques have been developed during the past 20 years to aid the executive in making decisions involving the allocation of limited resources among competing and interrelated demands. One such technique is linear programing which uses the mathematical theory of convex sets.[2, 3]

The air-lines industry has many allocation problems which can be solved by means of linear programing techniques. Ferguson and Dantzig have shown an excellent application of the transportation technique of linear programing in the air-lines industry.[4] Their paper discusses a method for finding the minimum cost solution of a hypothetical example involving the allocation of a fixed fleet of four types of airplane for carrying a specified number of passengers over five routes.

The purpose of this paper is to present another type of allocation problem—the assignment problem—and to illustrate how this problem can be solved neatly using the assignment technique of linear programing. The mathematical background of the assignment problem is given elsewhere and is, therefore, not repeated here.[5, 6]

Illustrative Example

For the sake of concreteness, we shall consider the following example which has been revamped from the industry to illustrate the application of the assignment technique: Outerspace Airlines has a contract on a retainer basis for transporting shipments of the Expeditious Cargo Company. The contract provides that, for a *fixed and uniform charge per ton*, Outerspace will fly the shipments of Expeditious Cargo Company from a single origin to different destinations.

Table 1
Dollar Cost of Aircraft-Cargo Assignment

Aircraft No. \ Cargo No.	11	12	13	14	15	16	17	18	19	20
1	390	420	700	830	260	870	710	990	220	940
2	470	600	450	290	480	640	880	620	0	20
3	980	360	530	90	760	280	350	790	400	700
4	200	650	230	570	740	160	240	970	500	190
5	210	140	500	520	170	470	280	670	630	50
6	170	780	300	0	150	100	800	680	300	910
7	910	530	30	640	660	390	980	160	240	810
8	490	170	770	570	790	400	950	80	480	200
9	290	880	180	590	660	620	880	70	30	260
10	800	740	60	260	600	770	370	990	20	790
Column Minimum	170	140	30	0	150	100	240	70	0	20

The contract enumerates different categories of cargo and stipulates that an aircraft must carry not more than one category in the same load. For instance, explosives and acids cannot be carried together on the same plane. Aircrafts are therefore equipped with special purpose racks which make them more suitable for some categories of cargo than for others. Each aircraft can complete only one round trip per day.

On a certain day, Outerspace has ten aircrafts available at the origin, and Expeditious has ten different categories of cargo to be shipped to various destinations. Since Outerspace is paid a flat rate per ton, its revenue for a given weight of cargo transported is fixed no matter what the assignment of aircraft to cargo categories. However, Outerspace can choose the minimum-cost assignment—i.e., assign ten aircraft to ten cargo categories in such a way that the sum of costs involved

* Research Associate, Operations Research Group, Engineering Experiment Station.

TABLE 2
Reduced Matrix

Air-craft \ Cargo Co. No.	11	12	13	14	15	16	17	18	19	20	Row Minimum
1	220	280	670	830	110	770	470	920	220	920	110
2	300	460	420	290	330	540	640	550	0	0	0
3	810	220	500	90	610	180	110	720	400	680	90
4	30	510	200	570	590	60	0	900	500	170	0
5	40	0	470	520	20	370	40	600	630	30	0
6	0	640	270	0	0	0	560	610	300	890	0
7	740	390	0	640	510	290	740	90	240	790	0
8	320	30	740	570	640	300	710	10	480	180	10
9	120	740	150	590	510	520	640	0	30	240	0
10	630	600	30	260	450	670	130	920	20	770	20

in flying shipments is minimized with a consequent maximization of profit.

We can now construct a cost table (Table 1) which shows the cost associated with assigning each of ten planes (numbered 1 through 10) to each category of shipment (numbered 11 through 20). Table 1 is called a *matrix*, and, since it has the same number of rows as columns, it is called a square matrix—more specifically a 10 by 10 matrix.

Some explanation for the cost figures entered in this matrix appears to be in order. These cost figures include only those elements of the cost which vary with the assignment. For instance, if the cost of the crew for a given plane is independent of the category of cargo the plane carries, this cost will not appear in the matrix. However, if the fuel cost varies with the weight of cargo carried, this cost will be included in the matrix.

Table 1 shows that the cost of assigning plane 6 to cargo category 14 is zero. This could happen in a situation where plane 6, after having delivered its cargo at destination, gets some pay load for the return trip, and the revenue from this return pay load is sufficient barely to cover that part of the cost of the round trip which is variable with this particular assignment.

To recapitulate, the problem is to assign one aircraft to one separate cargo in such a way that all ten planes are assigned and the total cost for all flights is minimized. It should be noted that in this case there are 10! (=3,628,800) possible assignments. A naive way of approaching the problem is to enumerate all possible assignments, "cost" each one of these (in our illustrative example the cost varies from a minimum of $1,210 to a maximum of $8,350), and select the minimum-cost assignment. Alternatively, the transportation method—a commonly used method of linear programing—could be used to determine the mimimum-cost solution. However, in this paper a special technique of linear programing called the assignment technique, developed by Flood, will be used.[5] This technique is particularly effective for solving such assignment problems.

ASSIGNMENT TECHNIQUE ILLUSTRATED

Step 1

Examine, individually, each column of the cost matrix (Table 1) for the mimimum-cost element, and write this element in the row below the matrix. For instance, the minimum element is $170 in column 11, $140 in column 12, etc.

Step 2

Subtract from each element of the matrix in Table 1 the minimum element in its column (determined in Step 1) thus obtaining a new matrix (Table 2). Table 2 will have at least one zero element in each column.

Step 3

Examine each row of the matrix in Table 2 for the minimum element, and write this element in the column to the right of Table 2. Thus, row 1 has minimum element 110, row 2 has minimum element zero, etc.

Step 4

Subtract from each element of the matrix in Table 2 the minimum element in its row (determined in Step 3) thus obtaining a new matrix (Table 3). Table 3 will have at least one zero element in each row and column.

TABLE 3
Reduced Matrix

	Air-craft \ Cargo No. No.	11	12	13	14	15	16	17	18	19	20	
	1	110	170	560	720	0	660	360	810	110	810	
	2	300	460	420	290	330	540	640	550	0	0	
	3	720	130	410	0	520	90	20	630	310	590	
	4	30	510	200	570	590	60	0	900	500	170	
	5	40	0	470	520	20	370	40	600	630	30	
***	6	0	640	270	0	0	0	560	610	300	890	***
	7	740	390	0	640	510	290	740	90	240	790	
	8	310	20	730	560	630	290	700	0	470	170	
	9	120	740	150	590	510	520	640	0	30	240	
	10	610	580	10	240	430	650	110	900	0	750	

*** indicates set of covering lines

TABLE 4
Reduced Matrix

	Air-craft No. \ Cargo No.	11	12	13	14	15	16	17	18	19	20	
***	1	80	170	560	720	0	630	360	810	110	810	***
	2	270	460	420	290	330	510	640	550	0	0	
	3	690	130	410	0	520	60	20	630	310	590	
***	4	0	510	200	570	590	30	0	900	500	170	***
	5	10	0	470	520	20	340	40	600	630	30	
***	6	0	670	300	30	30	0	590	640	330	920	***
***	7	710	390	0	640	510	260	740	90	240	790	***
	8	280	20	730	560	630	260	700	0	470	170	
	9	90	740	150	590	510	490	640	0	30	240	
	10	580	580	10	240	430	620	110	900	0	750	

*** indicates set of covering lines

TABLE 5
Reduced Matrix

	Air-craft No. \ Cargo No.	11	12	13	14	15	16	17	18	19	20	
***	1	80	180	560	730	0	630	360	820	120	820	***
***	2	260	460	410	290	320	500	630	550	0	0	***
***	3	680	130	400	0	510	50	10	630	310	590	***
***	4	0	520	200	580	590	30	0	910	510	180	***
***	5	0	0	460	520	10	330	30	600	630	30	***
***	6	0	680	300	40	30	0	590	650	340	930	***
***	7	710	400	0	650	510	260	740	100	250	800	***
	8	270	20	720	560	620	250	690	0	470	170	
	9	80	740	140	590	500	480	630	0	30	240	
***	10	570	580	0	240	420	610	100	900	0	750	***

*** indicates set of covering lines

Step 5

Examine all zeros in the new matrix (Table 3, in this case), and draw the *minimum* number of horizontal and/or vertical lines (called the set of covering lines) to include all zeros. If this set consists of ten lines, proceed to Step 7 to find the minimum-cost solution; otherwise proceed to Step 6.

Thus, in Table 3 the set consists of nine lines: row 6, columns 12, 13, 14, 15, 17, 18, 19, and 20 (marked * * *). Hence we proceed to Step 6. (It might be noted that the set of covering lines need not be unique. Thus in Table 3, an alternative set could consist of rows 1, 2, 3, 4, 5, 6, 7, and 10, and column 18, making a total of nine lines.)

Step 6

Examine each element of the new matrix, ignoring all rows and columns that are included in the set, and find the minimum element. In Table 3, this element is 30 (at the intersection of row 4 and column 11). *Subtract* this minimum element from each element of the new matrix that does not lie in rows or columns which are included in the set. Also, *add* this minimum element to each element at each intersection, if any, of rows and columns that are included in the set. The end result of these operations will yield another table.

Thus, Table 4 has been obtained from Table 3 by subtracting 30 from each element (there are 18 such elements in Table 3) that does not lie in a row or column marked * * * and by adding 30 to each element (there are 8 such elements in Table 3) that lies at the intersection of rows and columns marked * * *.

Step 7

Repeat Steps 5 and 6 until, for the first time, at some stage, the set of covering lines for zero elements in the table consists of exactly ten lines. Then, there is in this table (called the *final matrix*) a set of ten *independent zero elements*, and the elements of Table 1 in these ten positions constitute the required minimum-

TABLE 6
Final Matrix

	Air-craft No. \ Cargo No.	11	12	13	14	15	16	17	18	19	20	
***	1	80	180	560	730	(0)	630	360	840	120	820	***
***	2	260	460	410	290	320	500	630	570	0	(0)	***
***	3	680	130	400	(0)	510	50	10	650	310	590	***
***	4	0	520	200	580	590	30	(0)	930	510	180	***
***	5	(0)	0	460	520	10	330	30	620	630	30	***
***	6	0	680	300	40	30	(0)	590	670	340	930	***
***	7	710	400	(0)	650	510	260	740	120	250	800	***
***	8	250	(0)	700	540	600	230	670	0	450	150	***
***	9	60	720	120	570	480	460	610	(0)	10	220	***
***	10	570	580	0	240	420	610	100	920	(0)	750	***

The optimal assignment, which is unique in this example, is indicated by the symbol (0).

*** indicates set of covering lines

cost solution. *A set of independent zero elements* satisfies the following two conditions:

(1) Each row contains only one zero that belongs to the set.

(2) Each column contains only one zero that belongs to the set.

It might be added, parenthetically, that any row or column of the final matrix might actually contain more than one zero element; however, only one of these zero elements in each row or column will belong to the set of independent zeros.

To illustrate these concepts further, let us consider Table 4. Its set of covering lines consists of rows 1, 4, 6, and 7, and columns 12, 14, 18, 19, and 20, making a total of nine lines. Its minimum element, ignoring all elements which lie in rows or columns included in the set of covering lines, is 10 (element at the intersection of row 5 and column 11). We subtract 10 from each of the 30 elements in Table 4 which we get by ignoring all elements that lie in the set of covering lines. Also, we add 10 to each of the 20 elements which lies at the intersection of rows and columns of the set of covering lines. This gives us Table 5.

The set of covering lines in Table 5 consists of rows 1, 2, 3, 4, 5, 6, 7, and 10, and column 18, making a total of nine lines. The minimum element, ignoring all elements which lie in rows or columns of the set of covering lines, is 20 (element at the intersection of row 8 and column 12). We subtract 20 from each of the 18 elements of Table 5 which does not lie in the rows or columns of the set and add 20 to each of the 8 elements which lies at the intersection of rows and columns of the set and obtain Table 6.

TABLE 7
Optimal Assignment

Aircraft No.	Cargo No.	Cost (from Table 1)
1	15	$260
2	20	20
3	14	90
4	17	240
5	11	210
6	16	100
7	13	30
8	12	170
9	18	70
10	19	20
Total Cost of Assignment		$1210

TABLE 8
Steps Leading to Determination of the Set of Independent Zeros in Table 6

Step No.	Zero in Line	Eliminate Corresponding Row and Column
1	Column 20	Column 20 and row 2
2	Row 1	Row 1 and column 15
3	Column 17	Column 17 and row 4
4	" 16	Column 16 and row 6
5	" 14	Column 14 and row 3
6	Row 7	Row 7 and column 13
7	Row 10	Row 10 and column 19
8	Row 9	Row 9 and column 18
9	Row 5	Row 5 and column 11
10	Row 8	Row 8 and column 12

The minimum number of lines required to cover all zero elements in Table 6 is ten. Hence, according to Step 7, Table 6 is the final matrix and should give us a set of ten independent zeros (shown enclosed within parentheses in Table 6).

The significance of the zero enclosed within parentheses in row 1 and column 15 of Table 6 is that aircraft No. 1 should be assigned to fly cargo No. 15. Similar remarks apply to each of the remaining nine zeros which is enclosed within parentheses in Table 6. The complete optimal assignment has been shown in Table 7. The cost associated with this assignment is $1,210 (by reference to Table 1). It can be proved rigorously that no other assignment based on these data will cost less than $1,210.

SEARCH FOR OPTIMAL SOLUTION

There are some rather easy devices for finding the set of independent zeros in the final matrix. In general, if there is only one zero (called *lone zero*) in a row or column, this zero has to be included in the set of independent zeros. Having selected this zero, we delete from consideration the row *and* the column in which this zero appears and proceed to find more lone zeros. To illustrate the procedure for Table 6, we select the lone zero in column 20 and delete column 20 and row 2 from consideration. Next, we select lone zero in row 1 and delete row 1 and column 15 from consideration. We proceed in this fashion, and, after finding each lone zero, we delete the corresponding row and column. Thus, by successive elimination, we reduce the size of the matrix. Often, this method leads to the selection of the complete assignment as shown for the illustrative example by the ten steps in Table 8.

When this method does not yield the complete set of

TABLE 9
Maximum-Revenue Assignment

Aircraft No.	Cargo No.	Revenue (from Table 1)
1	14	$830
2	16	640
3	11	980
4	15	740
5	19	630
6	20	910
7	17	980
8	13	770
9	12	880
10	18	990
TOTAL		$8,350

independent zeros, the remaining zeros required to complete the set could often be found with some ingenuity and practice. Indeed, we have used the technique for solving 16 by 16 matrices by hand without any difficulty. When the matrix is large and difficulty is experienced in finding the set of independent zeros, graph-theoretic methods have to be employed.

A desirable feature of this technique is that it is self-corrective in the sense that, if during an application of Step 5 we make an error in selecting the minimum set of lines required to cover all zeros—such that the set selected consists of more lines than actually required—the computations are not thereby invalidated. This type of error is likely to be corrected automatically in subsequent applications of Step 5.

VARIATIONS OF THE PROBLEM

The optimal assignment technique illustrated in this paper is flexible enough to handle problems with many variations, such as the following (for further details, see Vaswani[6]):

(1) There might be more planes available than the number of flights required. This will generate a matrix that is not square. However, by introducing sufficient columns for "artificial flights," the matrix can be made square. Since these "artificial flights" are really not flown, all cost elements in the columns corresponding to the "artificial flights" will be zero. Having converted the matrix into a square matrix, the problem could be solved following the technique illustrated above.

(2) There might be legal or other restrictions prohibiting the flying of a certain cargo category in a specified plane. For instance, the weight of a cargo to be flown might exceed the maximum permissible pay load of a plane. Such a restriction can be taken care of by assigning, in the cost table, an infinitely high cost to the appropriate square at the intersection of the row corresponding to the plane and the column corresponding to the category of cargo. This will automatically prevent the assignment of the particular plane to the cargo.

(3) The problem might be one of maximization instead of minimization. For instance, the cost involved in assigning a plane might be fixed regardless of the flight to which the plane is assigned. However, the revenue might vary with the assignment selected. In such a case, the problem is to make such an assignment that the total revenue is maximized. We can start the solution by constructing a *revenue matrix* which will show the revenue to be earned by assigning each of the given planes to each of the flights and then solve the problem in the following manner:

(a) We find the largest element in the matrix and subtract from it each element in the matrix. This will yield a new matrix with all nonnegative elements and at least one zero element.

(b) We use this matrix as our first matrix and follow the same technique as for the minimization problem. This minimization assignment will correspond to the maximum-revenue assignment with respect to the original matrix.

Thus, if Table 1 represents the revenue matrix, Table 9 indicates the corresponding maximum-revenue assignment.

CONCLUSION

The assignment technique of linear programing could be used to solve optimal assignment problems in the air-lines industry. The application of the analytic technique developed by Flood, and illustrated in this paper, needs the ability to perform only simple addition and subtraction. Hence, it could be used routinely by clerical personnel, thus relieving the executive for the important decision-making function.

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The vertical variations of precipitation rate, liquid water content, radar reflectivity factor, and particle size distributions are examined in the cases of three models giving widespread precipitation. The derived quantities have application to the numerous applied problems in aeronautics and radar detection in which general estimates of the precipitation parameters are required.

A Model Atmosphere for Widespread Precipitation

David Atlas* and Edwin Kessler, III**

Geophysics Research Directorate
Air Force Cambridge Research Center

Introduction

There are innumerable applied problems in which knowledge of the precipitation content of the atmosphere and its effects on air-borne vehicles or radiation through the troposophere is required. Among such problems are (1) jet-engine water and ice ingestion, (2) aircraft and radome erosion by precipitation elements, and (3) masking of radar targets by precipitation clutter. It is therefore desirable to describe a sort of standard precipitation atmosphere which can be used with relative ease as an estimate of what might be encountered in a typical storm. Although the variability in the precipitation structure from one storm to the next and within any individual storm does not permit the establishment of a true standard, knowledge gained in recent years through studies in radar meteorology and precipitation physics now permits the construction of some storm models. The models to be discussed in this paper are based primarily on radar measurements by Wexler and Austin,[13] Atlas,[3] and Kessler and Atlas[7] and on combined aircraft-radar observations by Cunningham[5] and Cunningham and Atlas.[14] These hypothetical storms are not mathematical averages of a number of storms; they are simply what the authors believe to be typical of the conditions in the well-developed central region of widespread precipitation areas.

Other model cloud and precipitation systems were constructed by Atlas *et al.*,[1] hereafter referred to as "A." Although these earlier models were sufficiently accurate for approximate computations of microwave attenuation, they were not physically realistic in some respects. In particular, average precipitation or cloud contents were assumed through deep layers, and vertical variations were made in discontinuous steps. In the computation of the present storm structures, vertical variations of precipitation are smooth and are consistent with the moisture which can be condensed out of the atmosphere under the hypothesized motions.

It is desired to point out that the present precipitation models are based on steady-state solutions of the continuity equation for moisture and assume that all the water condensed out of the air goes over to precipitation. In other words, in the hypothetical storms there is no storage of water in the form of clouds. This is not realistic in the rain below the 0°C. level because rain can grow only by the collection of cloud droplets. Thus, there may be two or three times more water in the form of cloud than in the form of rain, especially just below the melting level. Above the level of about −3°C., snow and liquid water cloud rarely coexist except for brief transient periods. Therefore, the computations are fairly accurate in this regard in the snow region.

General

Condensation takes place when saturated air ascends. In deriving the results presented below, precipitation at the ground has been equated to the total condensation in three cases of horizontally homogeneous air. In each model, the air ascends at various rates in accord with a parabolic distribution of vertical velocity (with respect to pressure height). The equation describing the condensation process in terms of the individual changes of pressure is as follows:

$$R_0 = +\frac{1}{g}\int_{p_0}^{0}\frac{dq_s}{dt}\,dp = +\frac{1}{g}\int_{p_0}^{0}\frac{dp}{dt}\frac{dq_s}{dp}\,dp \qquad (1)$$

Here R_0 is the precipitation rate at the level desired, g is the acceleration of gravity, q_s is the saturation specific humidity of a parcel of air, and p is pressure.

* Chief, Weather Radar Unit.
** Weather Radar Unit.

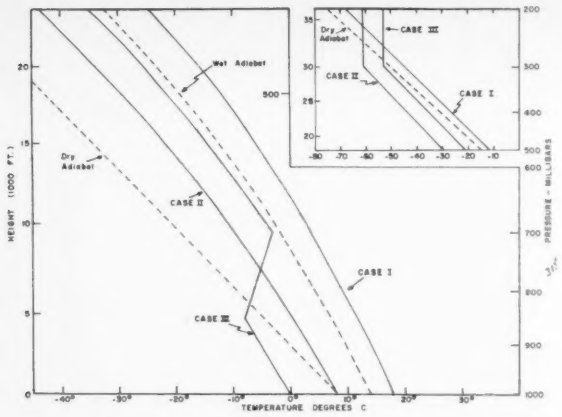

FIG. 1. Vertical temperature distribution of the models used in this study. In each case the atmosphere is considered saturated with respect to water throughout.

The last form readily lends itself to graphical determination using the standard meteorological diagrams when the distribution of dp/dt and temperature are known.

Fig. 1 illustrates the assumed vertical temperature distribution for the three cases studied. Case I is believed representative of a summer rain in temperate latitudes and, with a slight increase of temperatures, of widespread tropical rains generally. Case II may be associated with rain in the spring and fall months in temperate latitudes and also represents a likely thermal stratification during many orographic rains of temperate climes. Case III—patterned after the atmospheric structure of the blizzards of March 16 and 19, 1956, at Boston—is representative of a winter snowstorm and, except for the low temperatures, characterizes the winter rains as well. All cases pertain to widespread uniform precipitation only and not to showery conditions. Since the atmosphere in every case is assumed saturated throughout, the soundings of Fig. 1 also fix the distribution of q_s and dq_s/dp, given by the moist-adiabatic process.

The parabolic distribution of individual pressure change is given by a linear distribution of divergence with pressure through the hydrodynamic equation of continuity. The figures given in Table 1 which constitute the scale model for this study correspond to such a linear distribution of divergence, with zero value at 600 mb. The particular numbers chosen also correspond to divergence of -10^{-4} sec.$^{-1}$ at the ground.

Distribution of Precipitation Intensity With Height

Precipitation intensity as a function of height has been computed numerically by using the finite difference form of Eq. (1) and the Skew t-Log p diagram. The results are indicated in Fig. 2 for the 10-mm. hour^{-1} example of each case considered. The precipitation rate, or mass falling through a unit area per unit time, is given for all three cases because the spatial concentration of mass and the radar reflectivity values

TABLE 1

Vertical Velocity Distribution Corresponding to a Linear Distribution of Divergence Equal to -10^{-4} sec.$^{-1}$ at the Ground and 0 at 600 mb.*

Pressure p Height (mb.)	Approx. Height (ft.)	dp/dt (mb./sec.)	Updraft u (cm./sec.)
1,000	0	0	0
900	2,800	0.009	8.3
800	6,000	0.015	15.3
700	9,500	0.019	21.7
600	13,500	0.020	25.8
500	18,000	0.019	28.5
400	23,000	0.015	27.0
300	29,300	0.009	20.1
200	38,500	0	0

* The vertical velocities given here correspond to the following precipitation rates at the ground: Case I, 6.8 mm. hour^{-1}; Case II, 3.3 mm. hour^{-1}; and Case III, 4.2 mm. hour^{-1}. In order to obtain the vertical velocities corresponding to $R_g = 25$ mm. hour^{-1} in Case I, for example, multiply the values of Table 1 by $25/6.8 = 3.7$.

have been computed from their empirical relationships to precipitation rate. If the reader finds it desirable to recompute the latter curves based on somewhat different empirical relations, he may refer to Fig. 2. In order to find the precipitation rate at any height for rates at the ground other than 10 mm. hour^{-1}, simply multiply the value given by $R_g/10$, where R_g is the desired rate at the ground.

Distribution of Spatial Concentration of Precipitation With Height

The distribution of rain water content with height has been determined directly from the rain intensities using the empirical relation of Marshall and Palmer[10]

$$M = 0.072\, R^{0.88} \qquad (2)$$

where M is in gm. m.$^{-3}$ and R in mm. hour^{-1}. This equation is fairly representative of a large variety of both widespread and showery rainfall. However, it does not pertain to drizzle or Hawaii-type orographic rainfall and may be in error in individual cases. Other equations are given by Best[4] and Atlas.[2]

In the case of snow, a somewhat more elaborate

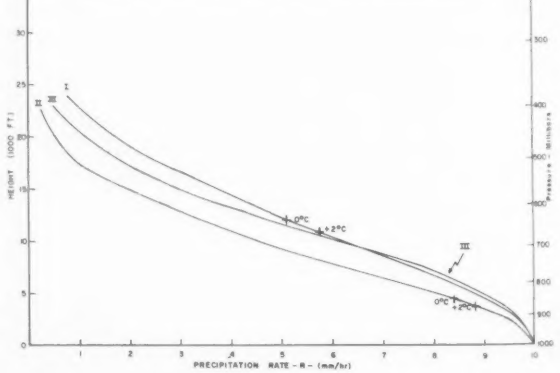

FIG. 2. Precipitation intensity as a function of height for the three model atmospheres of Fig. 1, all for a surface rate of 10 mm./hour. These curves are derived from parabolic distributions of vertical velocity (see Table 1) in saturated air, with precipitation equated to condensation.

TABLE 2
Assumed Variation of Terminal Fall Velocity of Snow Crystals and Flakes with Temperature

Temp. Range (°C.)	Fall Velocity v (cm./sec.)
less than −8	50
−8 to 0	50 → 100 (linear relation)
0 to +2	100 → 140 (linear relation)

method has been used in order to take account of the effects on the relatively slowly falling snowflakes of the rising currents which produce the condensation. We have assumed a monodisperse distribution of fall velocity at any one height for the purpose of the computations of this section, although we have allowed some variation of fall velocity with temperature, as shown by Table 2.

Consider now that for a monodisperse distribution

$$M = Nm \tag{3}$$

where N is the number of particles per cubic meter and m their mass. The precipitation rate in mm. hour^{-1} is given by

$$R = 3.6 \times 10^{-2} Nm(v - u) \tag{4}$$

where u is the updraft, and $v - u$ is therefore the fall velocity of the snow particles relative to the ground. The equations combine to give

$$M = R/[3.6 \times 10^{-2} (v - u)] \tag{5}$$

It is clear that, when the ascending currents equal or exceed the fall velocities of the particles relative to the air, the method given here cannot be used. However, it may be seen that the spatial mass concentrations may become quite large under such conditions. Presumably the precipitation would be suspended until it grew to a size large enough to overcome the updraft or would be carried up and horizontally away to fall out in a region where the local updraft velocities were not so strong. The tendency toward such high concentrations may be seen in the curves of Figs. 3, 4, and 5 for the higher surface precipitation intensities. This phenomenon may explain, at least in part, occasional radar observations of layers aloft during heavy snow. This has not been investigated further here because the problem in nature is quite complicated and few observational data on which to base a reasonable theory are available. Therefore no computations have been made for cases in which the updraft exceeds the terminal speeds of fall. Incidentally, no corrections have been made for updraft velocities in the rain since most raindrops fall much faster than any of the updrafts considered.

The computations have been carried out for various precipitation rates and corresponding updrafts (not exceeding the assumed fall velocities), and the results for selected precipitation intensities in the rain and snow are presented as Figs. 3, 4, and 5. The data are probably most reliable for the smaller precipitation rates.

As already noted in the introduction, water storage has been neglected in these computations. Therefore

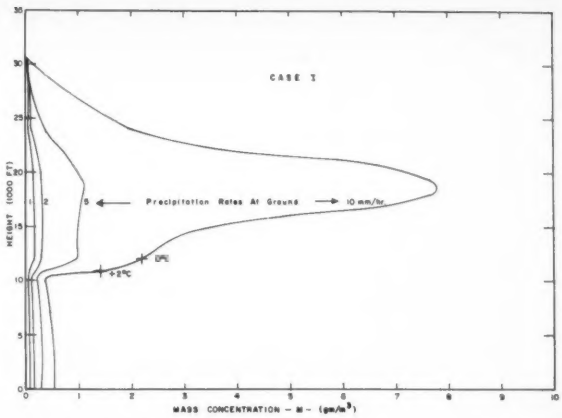

FIG. 3. Steady-state precipitation content of the air as a function of height for various surface rainfall rates for the case of a semitropical atmosphere, Case I. The peak near 18,000 ft. for 10 mm./hour rate is due to the near equivalence of updraft and fall velocity of snow particles. The drop in mass concentration below the melting level is due to the high speed of fall of the raindrops relative to that of the snow.

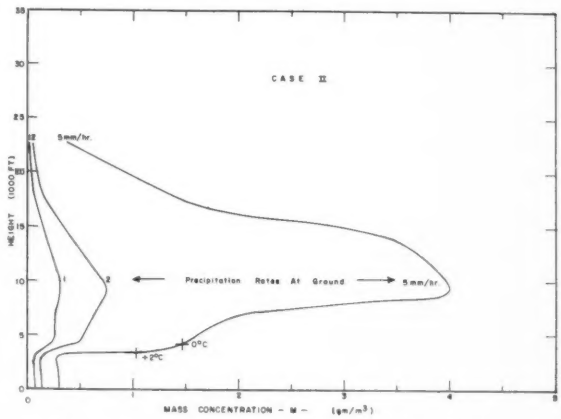

FIG. 4. Steady-state precipitation content of the air as a function of height for various surface rainfall rates for the case of a cool atmosphere with moist adiabatic lapse rate, Case II.

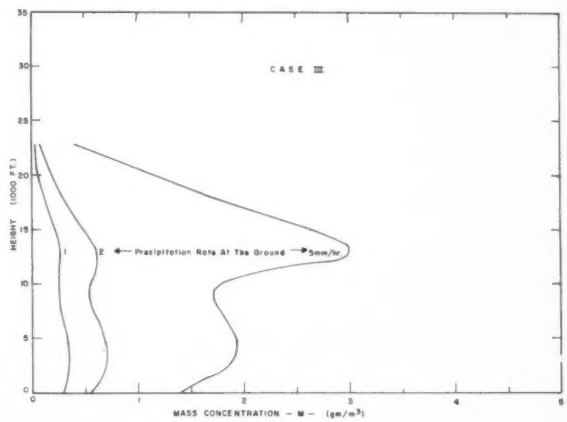

FIG. 5. Steady-state precipitation content of the air as a function of height for various surface snowfall rates for the case of a winter storm. The layers reflect the combined variations of precipitation rate, updraft, and fall velocities of the snow particles.

no water clouds are present in the model storms although they must occur in nature at least in the rain. In widespread rainfall, water clouds generally occur with base at 500 to 1,000 ft. and water content increasing upward to a maximum in the vicinity of the melting level—then decreasing to zero cloud content at a temperature level of about −2°C. Under steady-state conditions, the mass of water in the form of cloud may be two or three times that in the form of rain just below the melting level. This factor may be of considerable importance in some applied problems.

Particle Size Distributions

Work of Rigby, Marshall, and Hitschfeld[12] and Atlas[2] has shown that the distribution of particle sizes in rain and snow over an extremely wide range of meteorological conditions is given by

$$N_D = N_0 \exp(-3.67D/D_0) \qquad (6)^*$$

Here N_D is the number of particles per cubic centimeter per centimeter size range, and D is the diameter (melted diameter for snow particles) in centimeters. D_0 is the median volume diameter—i.e., the size which divides the distribution into two equal portions of water content. In rain,

$$D_0 = 0.09\ R^{1.21} \qquad (7)$$

and in snow,

$$D_0 = 0.14\ R^{0.48} \qquad (8)^*$$

where the reference is again to the melted diameter in cm. Both of these are only approximate, with wide variations in individual cases. N_0 is found to have a more or less constant value of 0.08 cm.$^{-4}$ in rain and is given by the very approximate relation

$$N_0 = 3.8 \times 10^{-2}\ R^{-0.87} \qquad (9)^*$$

for snow. Fig. 6 illustrates plots of Eqs. (6) (for rain only), (7), and (8) to facilitate determination of D_0 and particle size distributions in special cases of interest to the reader. Note that the plot of Eq. (6) given in Fig. 6 gives values of D/D_0 along the abscissa. To determine the actual distribution of sizes in a particular rain, one need only convert these to numerical values of D through use of Eqs. (7) and (8). In order to compute distributions in absolute units in snow, one should first compute $[v/(v-u)]N_0$, using Eq. (9) and the data of Tables 1 and 2 and Fig. 2, and apply this as the coefficient of Eq. (6) in place of the simple N_0.

Integrals of Diameter to an Arbitrary Power Over the Size Distribution

For various applications as outlined in Table 3, it is useful to be able to compute easily the quantity

$$\sum_{D=0}^{D=D_{max}} N_D D^k \simeq \int_0^\infty N_0 e^{-\Lambda D}\ D^k\ dD \qquad (10)$$

* Data for snow distributions were taken from Gunn, K. L. S., and Marshall, J. S., *The distribution with size of aggregate snowflakes*, McGill University, "Stormy Weather" Research, Scientific Report MW-20, Part B, 1956.

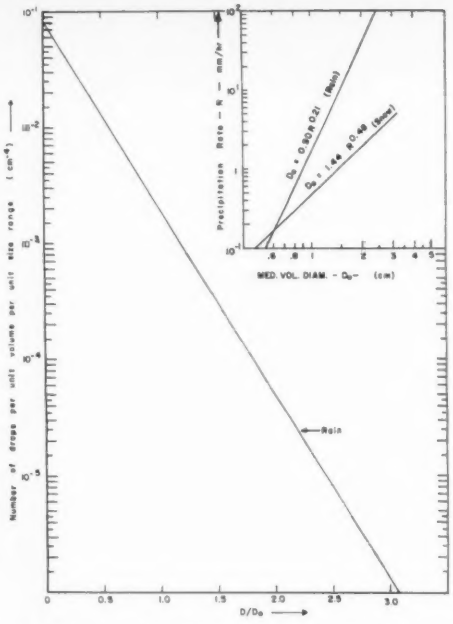
Number of drops per unit volume per unit size range (cm⁻⁴)
Precipitation Rate — R — mm/hr
MED. VOL. DIAM. — D_0 — (cm)
$D_0 = 0.09 R^{0.21}$ (Rain)
$D_0 = 1.46 R^{0.48}$ (Snow)
Rain
D/D₀

Fig. 6. Drop-size distribution functions for rain and snow. D_0 is the median volume diameter, that which divides a distribution into two portions of equal water content. (For further explanation, see text.)

The general form of the solution of this integral is

$$\int_0^\infty N_0 e^{-\Lambda D}\ D^k\ dD = N_0\ \frac{\Gamma(k+1)}{\Lambda^{(k+1)}}\ (k \geq 1; \Lambda > 0) \qquad (11)$$

where Λ is $3.67/D_0$, and Γ is the gamma function. For k not an integer, the computations may be made most readily with a table of the gamma function.

Radar Reflectivity as a Function of Height

Sufficient data have been provided by Gunn and East[6] and in "A" for the computation of the radar reflectivity of any precipitation of known intensity. In addition, microwave attenuation at various wave lengths was calculated as a function of height for a number of model weather situations. However, no attempt was made to compute curves of reflectivity versus altitude to indicate the intensity of radar echo which any assumed radar might receive under various weather conditions. With the more realistic precipitation models which have been developed in this paper, it is now feasible to compute such reflectivity-height curves.

It has been shown that the reflectivity per unit volume, η, of particles small relative to the wave length, λ, is given by

Table 3
Uses of the Integrals of the Particle Size Distribution to Various Powers

Quantity	Proportional to
ΣND	Evaporation or growth of a group of particles
ΣND^2	Optical extinction
ΣND^3	Mass concentration or water content
$\Sigma ND^{7/2}$	Precipitation rate for rain
ΣND^6	Reflectivity factor

$$\eta = (\pi^5/\lambda^4)K^2Z \times 10^{-12} \qquad (12)$$

where $Z = \Sigma ND^6$ is the summation of the 6th powers of the particle diameters in mm.^{6} m.$^{-3}$, λ is in cm., η in cm.$^{-1}$, and $K^2 = (m^2 - 1)^2/(m^2 + 2)^2$, where m^2 is the dielectric constant. Since the reflectivity factor Z is a function only of the particle size distribution and is completely independent of the radar factors, greater generality will be retained by plotting Z as a function of height for the model storms.

In the rain, values of Z are computed from the Marshall-Palmer[10] relation

$$Z = 200\ R^{1.6} \qquad (13)$$

where Z is in mm.^{6} m.$^{-3}$ and R is in mm. hour^{-1}, values of R being read from Fig. 2. In snow, use is made of the approximate equation

$$Z = [v/(v - u)]\ 500\ R^{1.6} \qquad (14)$$

at altitudes above the -8°C. level. The relation $Z = 500\ R^{1.6}$ applies to single crystal snow; it is arbitrarily assumed that the snow is in the form of single crystals above the -8°C. level. The modifying coefficient $v/(v - u)$ is used to account for the updraft velocity; values of u and v were obtained from Tables 1 and 2, respectively. Between the -8°C. and 0°C. level, use was made of the relation

$$Z = a\ R^{1.6} \qquad (15)$$

where the coefficient a varies linearly with height from 500 at the -8°C. level to 1,000 at the 0°C. level. The coefficient increases as the crystals aggregate to form larger and larger snowflakes (Imai *et al.*[8]). From the 0°C. level to the melting level, arbitrarily taken to be +2°C., Eq. (15) is used with a constant coefficient of 1,000. Although aggregation continues into the melting zone, and the coefficient in the $Z - R$ relation may rise to a value of 2,000, the processes in the melting zone are so complex and variable that a constant value of 1,000 has been assumed for simplicity. This does not differ greatly from reality on the average.

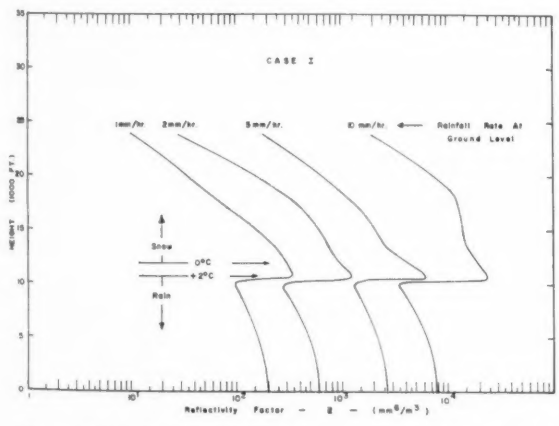

FIG. 7. Distributions of $Z = \Sigma ND^6$, the summation of the 6th powers of the particle diameters in the case of a semitropical atmosphere, Case I. The effects of updrafts are shown by the tendency for a layer near 20,000 ft. at the 10-mm./hour precipitation rate.

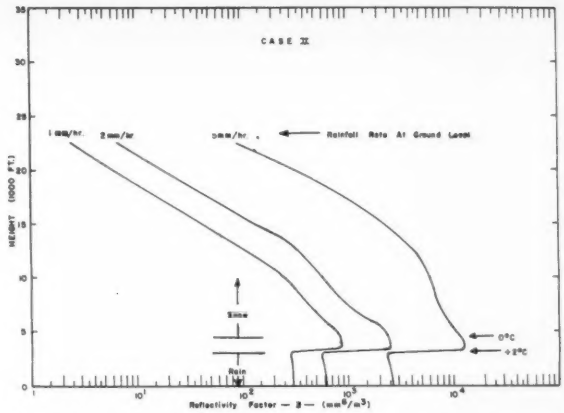

FIG. 8. Distribution of Z in the case of an atmosphere with moist adiabatic lapse rate and surface temperature of +8°C., Case II.

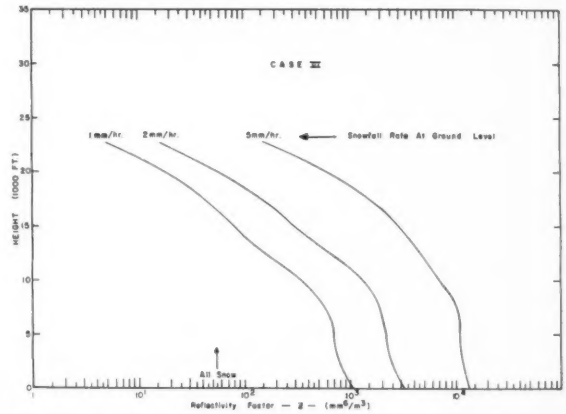

FIG. 9. Distribution of Z in an atmosphere characteristic of winter snowstorms, Case III.

The curves of Z versus height computed in the above manner are shown in Figs. 7, 8, and 9 for Cases I, II, and III, respectively. It will be noted in Figs. 7 and 8 that the Z values decrease discontinuously just below the 2°C. level where melting is completed and the particles accelerate to their raindrop velocities.

In order to calculate reflectivity values according to Eq. (12), one must also use the appropriate values of K^2. In this regard it is useful to know that the factor K^2/ρ^2, where ρ is the effective density of the scattering material, is constant. Thus, it is evident that K^2Z for ice crystals or snow of any effective density is equal to that which would result if the particles were fictitiously compressed to unit density (provided their sizes were in the Rayleigh region in the first place). This is fortuitous since the $Z - R$ relations for snow, Eqs. (14) and (15), have been calculated for their equivalent melted (unit density) diameters. Therefore, at temperatures below 0°C., one simply has to use the K^2 appropriate to unit density ice—0.19. In rain, $K^2 = 0.9$ is accurate to within about 5 per cent at centimeter wave lengths for all temperatures. More exact values of K^2 are given by Gunn and East.[6] Under certain restricted conditions K^2 may rise gradually from its ice value to that for water over the entire

FIG. 10. Picture of the range-height indicator of the CPS-9 radar, Blue Hill, Mass., 4:28 p.m. EST, October 15, 1955. Azimuth is 210°, range 25 miles. Widespread light rain is occurring, and the bright band which marks the melting level is evident near 12,000 ft.

melting zone (Langleben and Gunn[9]), but this need not be considered except for detailed radar observations through this zone.

Shaped particles, particularly of high refractive index, may return considerably more or less than spherical ones depending upon their nonsphericity and their orientation relative to the plane of radar polarization. In this regard, the low index ice crystals or snowflakes may be considered as spheres for most practical purposes. In the melting layer (0 to +2°C.), measurements indicate that the particles behave as slightly shaped, randomly oriented water particles with a reflectivity averaging about 1.4 times that of equal volume spheres. This factor too need be considered only in detailed studies of the melting layer. It is of considerable importance, however, in estimating the cancellation to be expected with circularly polarized radar. Whereas ordinary rain and snow echoes may be reduced by some 12 to 20 db. (average 16 db.), echoes from the melting layer may be reduced by an average of only some 7 to 17 db. (average about 12 db.) with circular polarization (Newell and Geotis[11]). Below the 0°C. level, the raindrops may be considered as spheres for most practical purposes.

It is evident from the above that the melting zone provides a characteristically more intense echo than either the snow above or the rain below. On a range-height or time-height radar record, this frequently appears as the well-known "bright band" such as shown in Fig. 10. Although such "bright bands" are particularly outstanding under the uniform conditions which occur with the lighter rainfalls, they occur also with widespread rains up to perhaps 30 mm./hour and more in intensity as may be found in a hurricane. In such a case, one may make only a rough approximation to the reflectivity in the melting zone since the particles may be suspended in very high concentrations in the strong updrafts which must exist. It is surmised that the coefficient a in Eq. (15) should have a value of perhaps 2,000 or 3,000 under such conditions in the melting layer.

For many purposes it is useful to compare the echo from a volume of precipitation to that from an ordinary target such as an aircraft. The equivalent target cross section σ (cm.^{2}) of precipitation is given by

$$\sigma = \bar{\eta}\, V \tag{16}$$

where V is the pulse volume (cm.^{3}) defined by the vertical and horizontal beam widths and *half* the pulse length in space. For a wedge-shaped beam of elliptical cross section (looking end on),

$$V = (\pi/8)\theta\phi\, r^2 h \tag{17}$$

where r is range and h is pulse length in space, both in cm., and θ and ϕ are the horizontal and vertical opening angles between half-power points in radians.

Note that the reflectivity per unit volume in Eq. (16) is written as $\bar{\eta}$, the average reflectivity over the pulse volume. Since a wide vertical beam may take in a large vertical extent of the atmosphere, one must integrate the reflectivity curves (K^2 times the Z values in Figs. 7, 8, and 9) as a function of height. For even greater accuracy, the reflectivity at each point in the illuminated volume should be weighted in proportion to the antenna gain relative to that along the beam axis. Such a refinement is not necessary in most practical cases, however, particularly with relatively narrow beams and short ranges of detection. Under the latter conditions the cross section calculated by means of Eqs. (16) and (17) may be reduced by about 25 per cent to account for the usual tapering of the pattern between half-power points. If the radar beam extends above the heights of the plotted Z curves, the reader may extrapolate the curves to 30,000 ft. This height may be considered as the top of ordinary widespread precipitation for most practical purposes.

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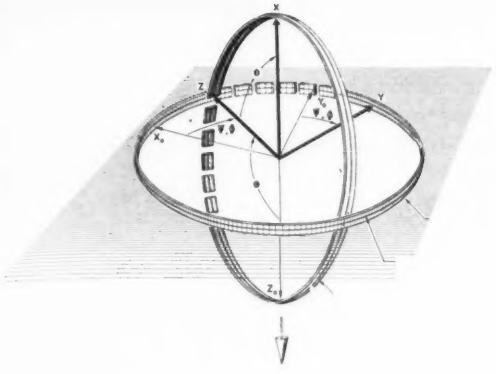
E. R. Hinz* and R. A. Fuhrman**
Ryan Aeronautical Company



Flight-Test Instrumentation for Vertical Take-Off Aircraft

The flight regimes of the jet VTO airplane are divided into the general classes of hovering flight, transition flight, and conventional flight. Although each regime presents its own instrumentation requirements, the final solutions must be compatible to yield an acceptable minimum weight system.

Introduction

Because the landing field length and surface requirements needed for the operation of high-performance airplanes have continued to increase at a distressing rate, a great deal of thought and effort in the past several years has been aimed toward the development of airplanes capable of vertical take-off and landing. This work is now culminating in the design of several different types of airplane with this capability, each developed for a specific application. This paper will consider the high-performance turbojet propelled airplane that takes off and lands in the vertical (or tail down) attitude. If the airplane is designed to take off and land vertically, it will not have to rely on normal landing fields, and therefore the weight of the conventional landing apparatus can at least partially be replaced by additional thrust-producing means, thus making it easier to meet the basic criterion for this airplane which is that the thrust-weight ratio must be in excess of one.

Flight testing is actually the final analysis in the development of any aircraft, and the vertical take-off airplane is no exception. We all realize that no aircraft design is completed until after it has been proved in flight, and this is particularly true of airplanes which represent a change from the conventional concepts. Flight tests must be used to check the basic analysis that went into the airplane design and to correct deficiencies that could not be determined by these prior analyses. If our analytical methods were perfect, flight testing would long since have been abandoned. However, we still find it necessary to obtain sufficient data to prove to both the purchaser and the producer that a flight article has been developed that will meet all of the pertinent operational requirements and also to determine the cause of any deficiencies that might exist. These flight-test requirements include, among other things, both the performance and handling qualities characteristics.

The vertical take-off airplane poses unique problems in flight-test operations, as well as in flight-test instrumentation, but we will be concerned only with the special instrumentation problems that have to be solved before we can satisfactorily complete the development of this type of airplane.

To the aircraft designer, the vertical take-off airplane poses a fairly complex problem in dynamic analysis. This analysis originally must depend on data that are estimated or obtained from wind-tunnel or laboratory tests for the determination of aerodynamic derivatives, servomechanism characteristics, and moments of inertia. In order to correlate the original design with flight tests, these same basic analyses must be rerun, based on flight-test results. This requires good data which in turn depend completely on accurate and dependable test instrumentation. The high degree of accuracy with which stability data must be known to achieve meaningful results from the simulation of complex maneuvers indicates the need for new and more exact methods of obtaining data during flight. As an example, the analysis of the landing transition of a VTO airplane requires the solution of six simultaneous nonlinear differential equations. From our experience, this can include about 30 nonlinear aerodynamic terms. It is therefore evident that, to measure these data in flight, very exacting instrument response characteristics must be obtained.

Because of the special weight considerations of the vertical take-off airplane, we cannot afford to overload it during flight testing with photopanels, recorders, or

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* Unit Chief, Systems and Controls.
** Chief, Technical Section.

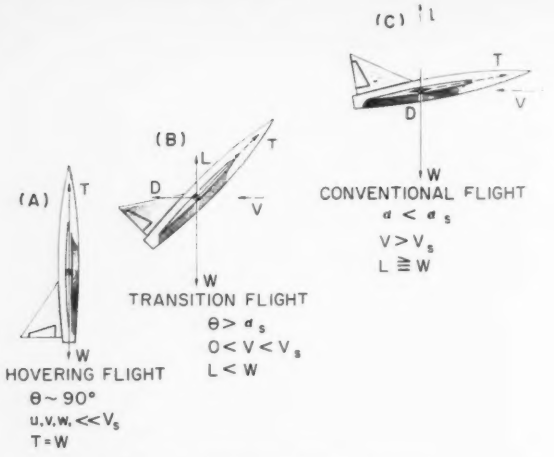


FIG. 1. VTO aircraft flight regimes.

any heavy end instruments. Since the airplane weight is uniquely controlled by thrust limitations, every pound of instrumentation that is added must be offset by removing some other item. This would generally require removal of other special equipment or fuel. For this reason, instrumentation for vertical take-off airplane flight testing must be designed to be light in weight besides satisfying other requirements.

VERTICAL TAKE-OFF AIRCRAFT FLIGHT REGIMES

From the standpoint of flight-test instrumentation, the vertical take-off aircraft poses unique problems primarily because it must operate in three fairly distinct regimes of flight, each with different characteristics in terms of handling qualities and the airplane performance. We generally define these regimes by hovering flight, transition flight, and conventional flight.

Hovering Flight

In order to execute a vertical take-off and landing, it is necessary for the aircraft to be able to hover about a fixed point. Hovering flight is then defined as the condition in which aerodynamic lift is essentially zero and the airplane weight is sustained solely by thrust. The pitch angle is of the order of 90°, and velocities are small. Fig. 1(A) schematically illustrates the hovering flight regime. The take-off and landing maneuvers are considered the end point of this regime of the VTO airplane. Since aerodynamic forces, with the exception of those due to steady winds and gusts, are small, the airplane must be both sustained and controlled through the use of internal thrust or power sources.

From the stability analysis standpoint, the hovering airplane can be considered a mass system having six degrees of freedom with essentially neutral inherent stability. Both static and dynamic stabilization must be supplied by the pilot or servomechanism devices. In hovering flight tests, we are primarily concerned with attitude and position measurement in order to determine how well the aircraft is being controlled in space. This, in turn, requires very exact dynamic measurements of control system response in order to correlate the controls functioning with the hovering airplane's motion.

In order to analyze performance characteristics in the hovering regime, thrust measurements are of importance. In addition, we are interested in velocity measurement under conditions where the dynamic pressure is extremely low, and we must therefore rely on nonstandard measuring techniques. To complicate our flight-test problems further, the time spent in the hovering regime must be limited. This is because of the high fuel consumption associated with the high powers required during hovering flight.

Transition Flight

The flight conditions encountered in changing from the vertical to the horizontal attitude define the second regime of flight peculiar to the vertical take-off airplane—the transition regime. We define this flight regime by the following set of conditions: Velocity is greater than zero but less than the stall speed, the pitch angle is greater than the stall angle of attack, aerodynamic lift is greater than zero but less than the aircraft weight, and therefore weight must be partially sustained by thrust. Both the accelerating (take-off) transition and the decelerating (landing) transition are covered by this definition. The transition flight regime is shown schematically in the diagram of Fig. 1(B).

Both aerodynamic and thrust producing sources must be considered for control and stabilization during the transition. Analyses have shown that, at angles of attack above the stall angle, positive stability can be provided longitudinally through the use of appropriate aerodynamic design. Generally speaking, however, the aircraft will exhibit negative lateral-directional stability regardless of the configuration used. Analyses have also shown that only coupled longitudinal and lateral-directional modes exist during transition, as well as in hovering flight.

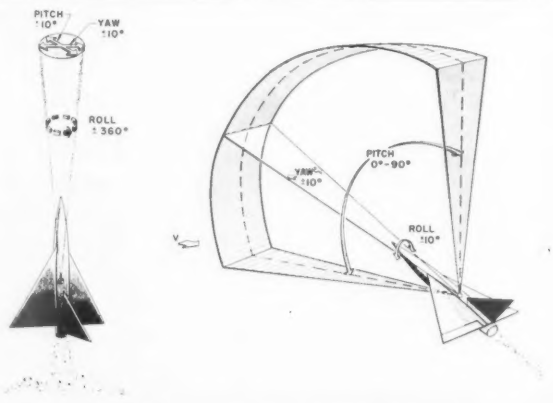


FIG. 2. (*left*). Hovering flight attitude envelope.
FIG. 3 (*right*). Transition flight attitude envelope.

Performance as well as control characteristics during the transition must be analyzed under transient conditions. We are concerned with how well the aircraft can be controlled and stabilized while being rotated from the vertical to the horizontal attitude or vice versa. This requires exact measurement of not only the position of the airplane in space at any instant but also the airflow relative to the airplane, particularly in terms of angle of attack and angle of sideslip.

Altitude, horizontal distance, and air speed must be known in addition to thrust output for performance analysis of the transition. Since the fuel consumption rate is high during the transition, minimum time to accomplish it is considered an important performance criterion.

Conventional Flight

Conventional flight is defined as the regime normally flown by present airplanes. By definition, aerodynamic lift is equal to or greater than the aircraft weight, velocity is greater than the stall speed, and the angle of attack is less than the stall angle. These conditions are illustrated by Fig. 1(C).

In conventional flight, the VTO airplane encounters all of the flight-test instrumentation problems of present-day high-performance aircraft. Because of the high thrust-to-weight ratio, the airplane inherently has exceptional performance characteristics in terms of ceiling, rate of climb, acceleration, and maneuverability. The rapid climb and acceleration characteristics aggravate the lag problem in pressure-type airspeed and altitude measuring devices. It is conceivable, for example, that this type of aircraft may have a rate of climb of about Mach 1 at low altitudes. This will require pressure transducers of extremely high response for speed and altitude measurement.

Since the vertical take-off airplane will probably require servomechanism devices to provide stabilization in hovering and transition flight, these same components will be used to provide stability augmentation in conventional flight. The operation of these special control components will have to be measured during all phases of flight.

The following sections will discuss possible solutions to some of the VTO airplane instrumentation problems, particularly the measurement of attitude in space and the velocity of the airplane.

Attitude Measurement

A most fundamental item of flight information is the aircraft attitude in space. An airplane, due to its three-axis maneuvering capability, can operate anywhere within a spherical space envelope over an extended period of time. However, since in flight-test work we try to call our shots, more limited spatial envelopes are employed. This has been particularly true in the past because of instrumentation limits and also because the more conventional aircraft could be suitably evaluated without recourse to extremely complicated methods. With the jet VTO airplane and its greatly increased operating flight region, we must take a broader look at the problem of defining the airplane's attitude in space.

First consider the hovering condition. The airplane is essentially sitting on its tail, and it gets translatory motion by an angular displacement of the resultant thrust which in turn causes the airplane to tilt off the vertical some small amount. Since our hovering airplane is strictly an inertial body, relatively unaffected by external aerodynamic forces, the direction of tilt (and of ensuing motion) is not unique. It is equally capable of tilting and translating in pitch and yaw or a combination thereof. Further, the airplane can be rolled about its longitudinal axis (which is vertical during hovering) without restriction. This freedom produces the conical hovering attitude envelope shown in Fig. 2.

We recognize the most obvious advantage of a VTO airplane to be its ability to hover, take off, and land vertically in a restricted space. Although the final

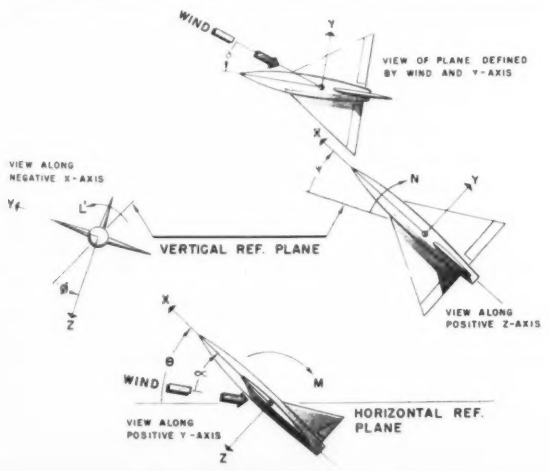


FIG. 4 (*left*). Body axes system.

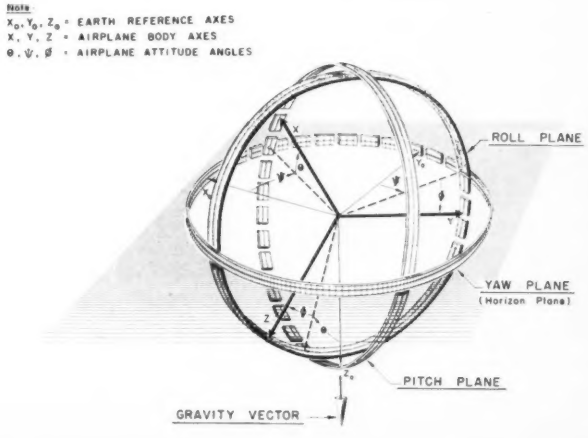


FIG. 5 (*right*). Euler axes system.

evaluation of this ability lies with the pilot's actually attempting such maneuvers, quantitative data on the airplane's behavior in the hovering attitude are essential to the complete development of the controls and other flight systems.

The second unique flight regime of the jet VTO airplane was shown to be the transition regime. Flight in this regime is considered merely a means to an end. Like the conventional take-off or landing, it is accomplished essentially in a vertical plane. At one extreme, the airplane's longitudinal axis is near-vertical, and at the other extreme it is near-horizontal. Because of the practical values of a vertical plane transition flight path, roll and yaw (measured about the body axes) are controlled within close limits. The resulting transition flight attitude envelope is shown in Fig. 3. Even though transition may be accomplished in a number of ways (horizontally through a wide angle of attack range, by zooming through a large altitude range, etc.), the airplane attitude will still undergo a change through the extremes of the illustrated envelope.

The third flight regime of the jet VTO is the conventional flight regime, and herein our attitude instrumentation requirements are similar to the more common types of high-performance jet aircraft.

None of the three space envelopes discussed appear to be important problems in themselves. Where we do run into difficulty is in blending them into a single all-inclusive envelope. This is a necessary and important step for two reasons: (a) We must have continuity of data among the three flight regimes, and (b) a single instrumentation system must generally provide the data for all regimes. The latter requirement is in keeping with fundamental VTO design criteria wherein weight (and, to some extent, volume) considerations are of major importance. Recognizing this in instrumentation, as well as in the basic airframe/engine design, means that we must extract from each instrument a maximum of information. Succeeding sections will discuss separately the data continuity problem and attitude instrumentation concepts.

The Body Axes

Because of the fact that the VTO aircraft traverses large angular distances and because the flight dynamics are nonlinear in nature, it is impossible to refer the flight motions to the well-tried stability axes system. Instead, reference is made to a true body axis which moves with the airplane. Three separate quantities are measured with respect to these body axes: (a) the orientation of the relative wind vector, (b) the instantaneous deviation of the air frame from vertical and horizontal reference planes, and (c) the attitude of the air frame in space. These three quantities are measures of the aerodynamic forces, inertial (and gravitational) forces, and flight path, respectively. Fig. 4 illustrates this body axes system and defines the wind vector orientation and the instantaneous airframe attitude angles.

The basic deficiency which arises in using the foregoing body axes system for free flight reference comes from the dual source of true azimuth indication. Changes in azimuth as correctly measured in the horizon plane must be found from the relation

$$\psi_{azt} = \psi \cos\theta + \varphi \sin\theta$$

Although mathematically a simple expression, it is not a simple flight instrumentation problem, as will be seen later.

Conventional Euler Axes

The previous body axes system may correctly be called Euler axes because they have their origin at the airplane center of gravity and their orientation with respect to the air frame is fixed. However, since they do not directly use a true azimuth reference, their application as a jet VTO flight reference is not too good. As an alternative, let us examine another Euler axes system which uses a true azimuth reference. Fig. 5 shows such a system as developed in reference 1. All the basic essentials of a space axes system are present here. Azimuth angle (ψ) is measured in the horizontal plane, pitch angle (θ) is measured in a vertical plane which contains the X-axis, and roll angle (φ) is measured in a plane normal to the X-axis.

Two undesirable features of this conventional Eulerian axes system are present. The first objection is that the order of rotation must be preserved (ψ, θ, φ in that order for the illustration) which does not give us the spatial measuring freedom we are seeking. The second undesirable feature arises in the handling of the azimuth angle ψ. At low angles of pitch we can measure the azimuth angle using the horizontal displacement of the X-axis which will be suitable for all roll angles. However, as we proceed to high angles of pitch as is done in transition, the angle ψ becomes increasingly less accurate measured with respect to the X-axis and reference must be shifted to the Y-axis. In the extreme situation when $\theta = 90°$, the angles ψ and φ become coincident as the roll plane has blended with the yaw plane. This, then, leaves our space position undefined for hovering as shown in Fig. 6.

Space Plane Axes

It is apparent that we are rapidly narrowing the possibilities of a space reference system to one which is composed of three mutually perpendicular planes with a fixed gravity orientation. Such a system is shown in Fig. 7. The basic reference here is the horizon (yaw) plane which always remains in the horizontal position. Perpendicular to this and containing the airplane X-axis is the pitch plane. Perpendicular to both the yaw and pitch planes is the roll plane. The intersection of the pitch and roll plane is aligned with the gravity vector. (Since the flight-test operations of a jet VTO airplane will take place within a small geographical area, no compensation need be made for the shift in the gravity vector's direction in space due to movement around the earth's periphery.)

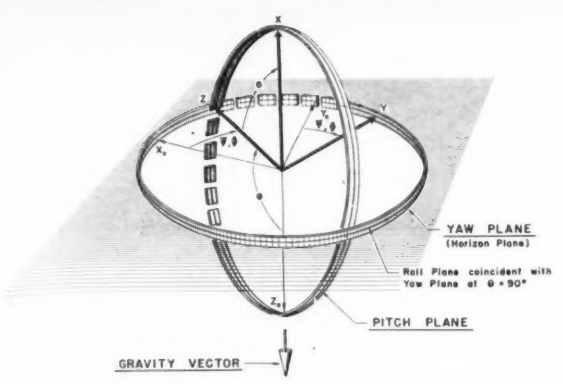


FIG. 6 (*left*). Euler axes limitation in hovering.

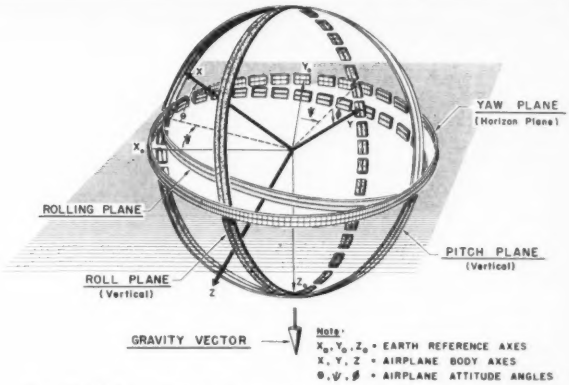


FIG. 7 (*right*). Space plane axes system.

The three desired spatial angles are now measured in the following manner:

Heading or yaw angle (ψ) is measured in the yaw plane as the angle between an arbitrary initial direction (X_0) and the intersection of the pitch plane. Pitch attitude (θ) is measured in the pitch plane as the angle between the yaw plane and the X-axis. Roll attitude (φ) is measured with the help of an auxiliary "rolling plane." This plane passes through and rotates about the intersection of the yaw and pitch planes and contains the Y-axis of the airplane. The roll attitude (φ) is measured in the roll plane as the angle between the yaw plane and the "rolling plane." Once having oriented the space planes, absolute space angles can be determined for any airplane attitude without restriction to small deviations or order of measurement.

Attitude Reference Instrumentation

The usual air-borne attitude reference source is the long familiar gyroscope. Built with a pair of gimbal rings, this gyroscope is capable of measuring two degrees of freedom. A two degrees of freedom gyro in which the spin axis is positioned in line with the gravity vector is known as the vertical gyro and can be used to give pitch and roll attitude reference within limits. The same two degrees of freedom gyro with the spin axis positioned normal to the gravity vector is known as the directional gyro and can be used to give azimuth reference. A description of the functioning of the vertical gyro is given in reference 2, and specifications for a typical unit are given in reference 3.

However well the conventional vertical and directional gyros have served as attitude sensors for conventional flight, they have serious shortcomings in the total VTO flight regime. Foremost among these is the problem of gimbal lock. This limitation is encountered as the pitch attitude angle approaches 90° and the inner and outer gimbals tend toward alignment in the same (vertical) plane. A second deficiency in the present off-the-shelf vertical gyro design is the limited angular freedom of movement.

Although it is conceivable that both the gimbal lock and limited freedom deficiencies could be overcome, it would not be accomplished without extensive (and expensive) development. Furthermore, we still do not have a means of measuring the azimuth angle. Conventional magnetic or gyro compasses representing the best state-of-the-art of azimuth measurement can function properly only when kept in a near horizontal plane.

The answer to our problem appears to be in the application of recent developments in the "stable platform" concept. This device, which was developed to be the key source of spatial attitude reference for inertial guidance and other automatic control systems, is ideally suited to our purpose. Several companies are developing these stable platforms, and a typical development is the Lear All-Attitude Reference Unit shown in the diagrammatic sketch of Fig. 8.

The vertical gyro rotor maintains its vertical position by pivoting freely about the (lateral) pitch axis and the fore and aft roll axis. This gyro then yields pitch and roll attitude from the "pitch output synchro" and the "inner roll pickoff." The directional gyro rotor is maintained in its horizontal position by essentially being floated in a triple gimbal ring. Again the outer gimbal is driven by the "roll follow-up servo" to hold a lateral horizontal reference while the middle gimbal is kept vertical by the "pitch follow-up servo and synchro." The inner gimbal then is free to rotate in azimuth to yield heading reference. Other "stable platforms" may use three gyros, but the end results are intended to be the same.

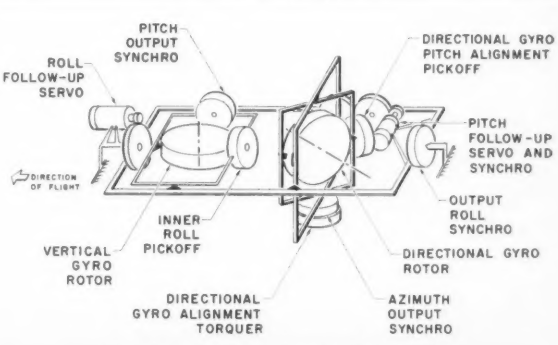
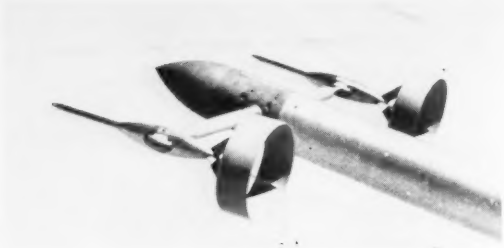


FIG. 8. Lear all-attitude reference unit.



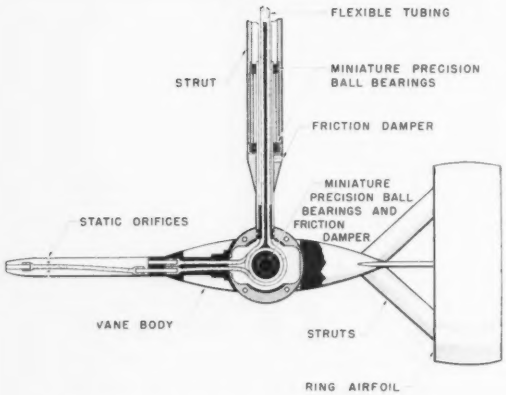


FIG. 9 (*top*). Task velocity measuring unit.
FIG. 10 (*bottom*). Task swiveling pitot-static head.

The data output from this device is in accordance with the space plane angles of Fig. 7. Such data will adequately describe the attitude of the jet VTO in any of its flight regimes.

VELOCITY MEASUREMENT

Since the aerodynamic forces on the airplane are significant in transition, it is considered essential to know the relative air velocity. In order to measure the true air velocity vector during transition flight, a special wind vane with two degrees of rotation has been developed. The unique feature of this design is its ability to measure large angles of attack and yaw at relatively low air speeds.

The instrument described here was developed by the Task Corporation of Pasadena, Calif., and is shown mounted on a nose boom in Fig. 9. A schematic is shown in Fig. 10. Two nearly identical two degree of rotation swiveling heads are located diametrically opposite each other on the nose boom tip. These measure flow direction and pitot-static pressures, respectively. The heads swivel to align themselves with the external airflow.

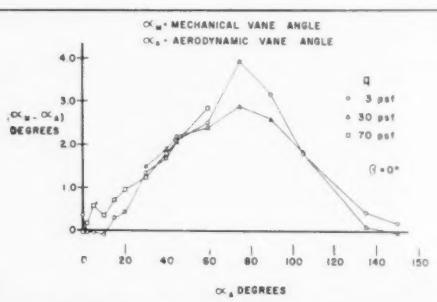
The flow-direction head has two toroidal potentiometers centered on the two axes of rotation which yield electrical signals proportional to the angle of attack and angle of sideslip. The angles measured are based on the body axes convention of Fig. 4. Calibration of the flow direction head was done in the California Institute of Technology GALCIT wind tunnel. Tests were run at variable dynamic pressure through wide angles of attack and sideslip. Typical angle deviation data from these tests are shown in Figs. 11 and 12. Because of some tunnel limitations, only one value of combined angles could be checked, and these were of accuracy comparable to that shown in the figures.

The second swiveling head was designed to measure total and static pressures in the conventional manner. Since the head centerline was always aligned with the airflow, maximum accuracy of the pitot-static reading was assured. Location of the static orifices was determined by tests in the Free Surface Water Tunnel at Caltech Calibration of the pitot-static readings using the complete head assembly took place in the GALCIT tunnel over a range of angles of attack and sideslip and dynamic pressure. Typical static pressure calibration curves are shown in Figs. 13 and 14. The maximum misalignment of about 4° at an angle of attack of about 80° shown in Fig. 11 will not produce a significant error in the pitot pressure as is discussed in reference 4. The major cause of error in the static measuring system is traceable to the influence of the unsymmetrical support system on the flow field.

As a matter of interest, other design studies and tests which were made on this device are boom bending under air load, boom natural frequency, dynamic response of the swiveling vanes, and potentiometer noise and static calibration.

A complete description of this unit and the calibration results may be found in references 5 and 6.

As has been indicated, we are also interested in velocity measurement during hovering flight. This is an operational as well as a flight-test requirement since it is imperative that the pilot know how well he is controlling vertical velocity, particularly during a letdown from altitude. From our own experience, it did



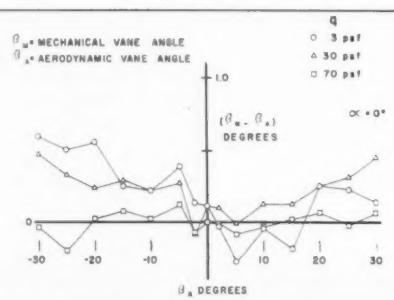


FIG. 11 (*left*). Angle of attack calibration. FIG. 12 (*right*). Angle of sideslip calibration.

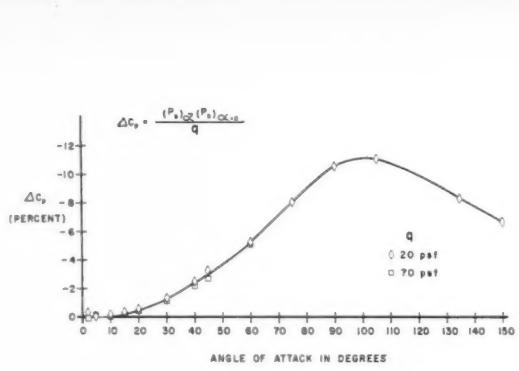


FIG. 13 (*left*). Static pressure calibration in pitch.

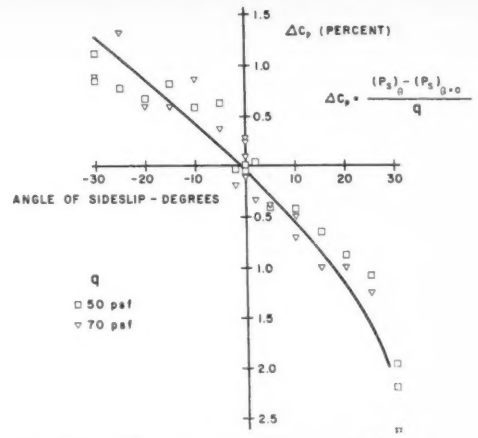


FIG. 14 (*right*). Static pressure calibration in sideslip.

not appear feasible to depend on any standard static pressure source and pressure recording instrumentation for this information. Studies have indicated, however, that continuous wave radar-doppler techniques could be used to advantage to solve this requirement. The Ryan Aeronautical Company has developed a helicopter hovering detector and navigation components using the continuous wave radar-doppler principle. This equipment has been modified to furnish a sensitive vertical velocity indicator of exceptionally light weight. The unit is capable of measuring vertical velocity to accuracies of about ±1 ft./sec. at velocities between ±20 ft./sec.

Other Instrumentation Considerations

We have discussed several of the major instrumentation problem areas unique to the jet VTO airplane; however, there remain a number of other instrumentation requirements worthy of mention. In hovering and throughout part of the transition, the conventional aerodynamic controls are inadequate, and consequently supplementary control means must be provided. The most obvious control means to use are those associated with jet reaction forces. These may be derived from deflection of the main jet stream or from some auxiliary source. In either case, the reaction controls must be adequately instrumented to yield position data, thrust level, and any other parameters considered necessary to establish the control moment vectors and time response.

Use of a stability augmentation system, automatic controls, or any other of the latest techniques for improving and controlling airplane flight will require a certain amount of in-flight monitoring. Although the pilot's ability to control the airplane adequately is the most positive proof of the airplane's ability to fly, continued development depends on knowing how the various critical components are behaving. Hence, when using artificial stabilization and control systems, they must also be adequately instrumented to measure input displacements, rates, accelerations, etc., and the corresponding outputs. Adequate instrumentation dictates that the accuracy of the measuring elements be of a higher order than that of the quantity being measured. This is a particular problem when monitoring stabilization systems containing highly accurate components.

It is not generally feasible to record all these data "on board" the test airplane. This is particularly true in the jet VTO where space and weight are critically controlled items. We therefore must depend to a large extent on telemetered information. This may be supplemented by a minimum of oscillograph recording of critical items in the test airplane.

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Beryllium as an Aircraft Structural Material

(*Continued from page 55*)

necessary before beryllium can be further considered as an aircraft structural material.

The investigation of the brittleness problem appears possible along two lines of approach—a basic research attempt at reducing the brittleness of beryllium and a structural evaluation of the best metal available at any one time. Reduction of brittleness may possibly result from higher-purity metal, from a better knowledge of the crystallography, from finding beneficial alloying additives, or from better production techniques. A structural evaluation might consist of tests of the best metal for tension and compression stress-strain curves (uniaxial and biaxial), static tests on joined sheets, fatigue tests, short-time and creep tests at elevated temperatures, etc. Complete, built-up structural elements might be assembled and tested in buckling.

If such research were to produce an acceptable metal, beryllium would become a valuable addition to the family of structural materials.

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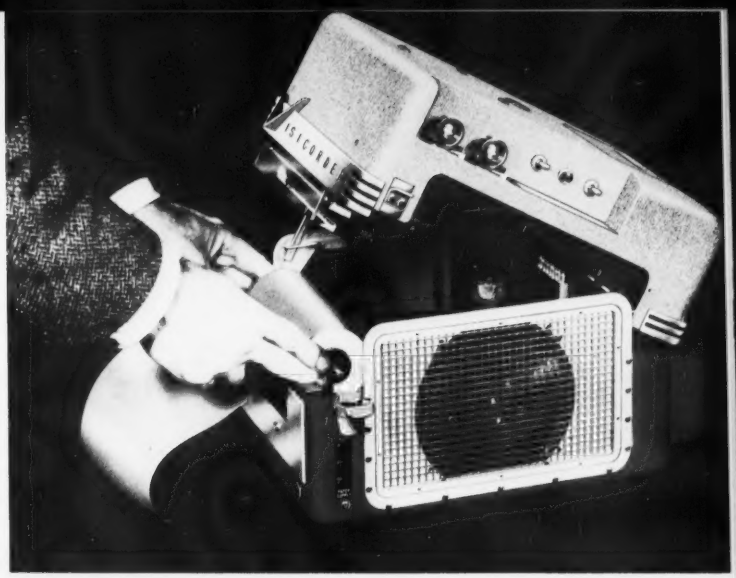

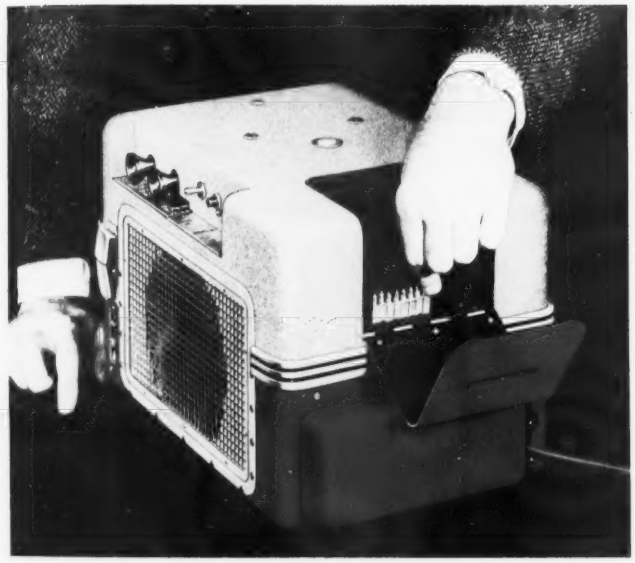

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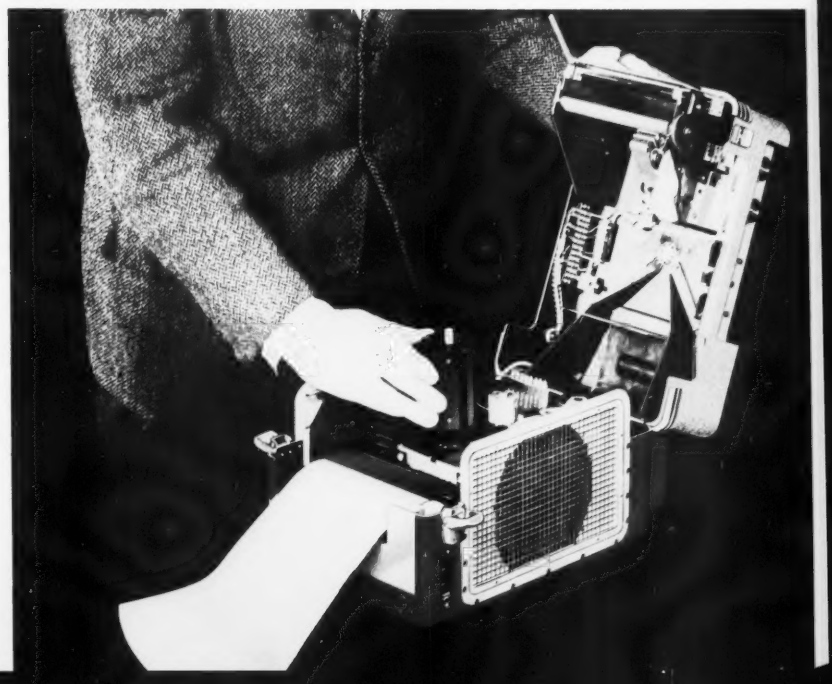

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The versatile Visicorder will fit almost unlimited applications because of its high frequency and sensitivity characteristics, and because of its ease of operation.

In any application where instantaneous monitoring is needed, whether or not a record is desired, the Visicorder is ideal.

★ **In CONTROL** applications the Visicorder will continually monitor and record reference and error signals, and present an immediately available recording of information.

★ **In NUCLEAR** applications, the Visicorder will monitor and record temperatures, pressures, and all other phenomena needed.

★ **In PRODUCTION TEST** applications, the Visicorder will provide a final dynamic inspection of electrical and mechanical devices such as motors, relays, generators, governors, solenoid valves, etc., where high frequency response has been required, but unavailable in the past.

★ **In COMPUTING** applications, the Visicorder will provide immediately-readable analog recordings representing dynamic solutions at much higher frequencies than have ever been available via pen—and-ink-type recorders previously used for this work.

★ **In PILOT and COMPONENT TESTING,** the Visicorder will accomplish more rapid evaluation of design and prototypes than any other direct-writing oscillograph available.

★ **In MEDICAL** applications the Visicorder is useful for dynamic blood pressures, electrocardiograms, EEG, and other physiological measurements.

★ **In all TEST** applications the direct-recording features of the Visicorder are invaluable. Where complex tests involve the assembly of considerable equipment and the gathering of personnel, the immediate Visicorder record will prove the success of the test at once before the test equipment is dispersed.

For further information about the Visicorder, contact the Minneapolis-Honeywell Industrial Division Sales Office nearest you. Sales-service facilities in over 130 principal cities throughout the world.

700-C Series Recording Oscillographs
Galvanometers
Bridge Balance Units
Amplifier Systems
HEILAND Photo-Flash Equipment

MINNEAPOLIS **Honeywell**

HEILAND INSTRUMENTS

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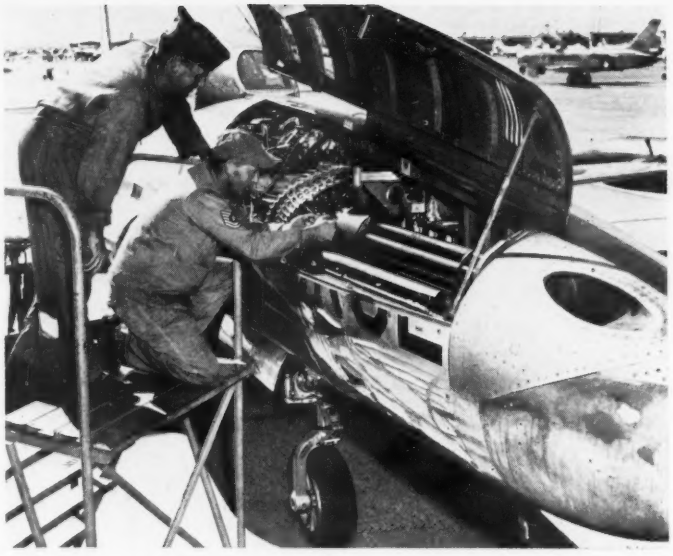


Vulcan, an electrically operated 0.20-mm. cannon seen in an F-94 jet fighter, is considered the world's fastest firing aerial cannon. Six rotating barrels spew more shells in 20 sec. than 400 riflemen shooting for 1 min., according to General Electric Company that helped develop the Vulcan with the Army and Air Force.

Corporate Member News

(*Continued from page 47*)

ing and Plating and Welding departments. William H. Chester and Charles W. Thomas have been appointed Assistant Supervisors of the Telemetry Engineering Section. Sales, engineering, and service for the division's Electro-Span Digital Remote Control and telemetering equipment have been set up through association with Computing Devices of Canada in Ottawa.

• **Boeing Airplane Company** manufacturing research engineers report they have found that at room temperatures 6 Al-4V titanium can be formed in a curve having a radius six times the thickness of the material. Operations possible at room temperatures are sheet-roll-forming and stretch-forming of sheets and sections. At elevated temperatures, the same titanium alloy can be formed in a curve having a radius three times the material thickness.

• **Douglas Aircraft Company, Inc.,** has concluded a 3-day DC-8 training conference for some 50 representatives of major world air lines at the firm's Santa Monica Division. Purpose of the conference was to present a training program for the air lines to help prepare their personnel for inauguration of jet transport service. An order for three intercontinental models of the DC-8 was received from UAT French air lines, an independent carrier now operating DC-4's and DC-6's. Four DC-6B's have been ordered by Linea Aerea Nacional de Chile.

• **The Dow Chemical Company** has published a new *1957 Reference Guide to Dow Corning Silicones* and has prepared a booklet, *Low-Cost Pole Buildings for Industry*, describing advantages of pole-type construction as a means of obtaining needed space at minimum cost. Copies may be obtained from The Dow Chemical Company, Midland, Mich.

• **Fairchild Engine and Airplane Corporation's** Aircraft Division delivered its first C-123 assault-logistics transport to the Tactical Air Command's 464th Troop Carrier Wing, making it the fourth Air Force organization to be equipped with the transports. Colonel L. J. Barrow, Wing Executive Officer, took delivery at the division's Hagerstown, Md., plant.

• **Federal Telecommunication Laboratories, Division of International Telephone and Telegraph Corporation,** has established a branch communications laboratory at Palo Alto, Calif. A new electronic "traffic cop" that prevents unwanted frequencies from interfering with the operation of radio equipment has been developed. The device is technically called a magnetostriction filter.

• **The Garrett Corporation . . .** AiResearch Manufacturing Co. will supply cabin air-conditioning and pressurization systems for the Lockheed Electra.

• **General Dynamics Corporation . . .** The engineering co-op plan at Convair Division, Fort Worth, has added three more schools to its list of participating colleges and universities: Northwestern University, Purdue University, and Missouri School of Mines. Students of participating schools rotate between on-campus study and work in various sections of Convair's Engineering Department.

• **General Electric Company** has announced the creation of a new operating department to meet demands of the communications market. To be known as the Communication Products Department, it will absorb functions handled before by the Communication Equipment Section. Products will include mobile radio, microwave radio relay, radio traffic coordination units, power line carrier equipment, terminal equipment, and other communication systems . . . . A new $8 million testing device which "thinks" faster than a guided missile will be put into operation at Holloman Air Force Base next year. Called a "real time" closed-loop analysis system, it will permit one flight test to give data now obtainable only through several tests. Engineers in the Electronics Division Missile and Ordnance Systems Department have joined two high-speed computers to reduce data from the first few minutes of the missile's flight . . . . Aircraft Gas Turbine Division engineers have devised a new aircraft hydraulic turbopump which provides a big fuel saving and contains a safety feature. It supplies power to actuate landing gear, bomb bay doors, control surfaces, and other components by converting compressed air from the jet engine to hydraulic power. It is completely automatic, 60 lbs. lighter, and contains one third as many parts as its predecessor . . . . Tests have been completed on the division's T58 turboshaft engine, soon to power Sikorsky HSS and Vertol H-21 helicopters . . . . The Chemical & Metallurgical Division has announced that prices on several of its product lines have been increased 5 to 10 per cent. Carboloy carbide blanks, standard tools, and Hevimet alloy will be affected. A new price list covering the carbide blanks has been published.

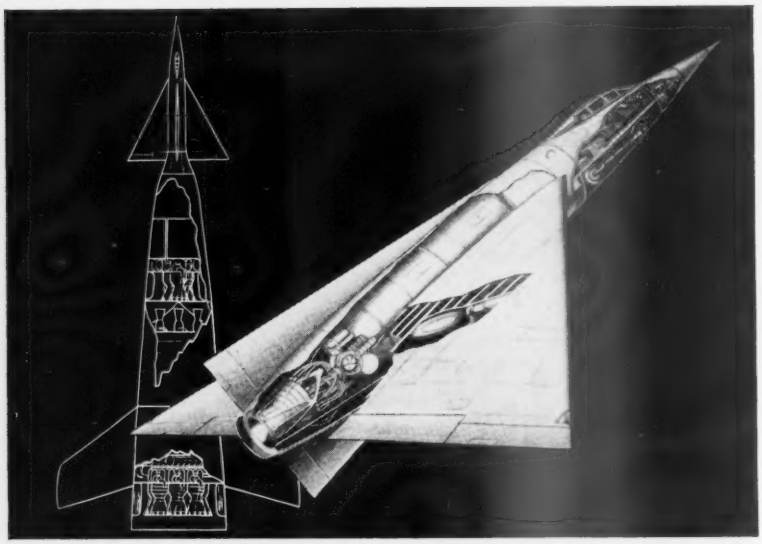
• **General Precision Equipment Corporation . . . .** Promotion of six executives and the broadening of facilities for research, development, and production have been announced for General Precision Laboratory Incorporated. Additional production facilities were made available by the parent firm, ground has been broken for a second engineering building at Pleasantville, N. Y., and a new environmental test laboratory there is scheduled to open this month.

• **Goodyear Tire & Rubber Company, Inc.,** has constructed a radiation laboratory adjacent to its Akron research facilities. Reportedly the first of its kind in the rubber industry, it is being used for exploration and development of rubber products which will perform satisfactorily in a radiation environment.

• **Harvey Aluminum Division of Harvey Machine Co., Inc.,** has a new 8,000-ton hydraulic forging press in operation at its Torrance, Calif., plant. Close tolerance-type aluminum forgings for aircraft structure are being produced.

• **Kollsman Instrument Corporation** has undergone reorganization to keep pace with expansion in the manufacture of new and complex navigation systems. Phillip F. Weber, former Factory Manager, has been appointed Assistant to the President with responsibility for monitoring production, providing interdepartmental liaison, and maintaining central analysis for all instrument systems. Frank Dupre (AM) has been appointed Manager of Manufacturing, and William McGurn is the new Superintendent of the Assembly Department . . . . A new line of pressure Synchrotel transmitters devised by the firm's engineers is reported to reduce response time in high-speed aircraft and guided missiles. The new instruments transduce pressure values as electrical signals and are lighter, more compact, and have less internal static volume than previous models.

MARS outstanding design **SERIES**

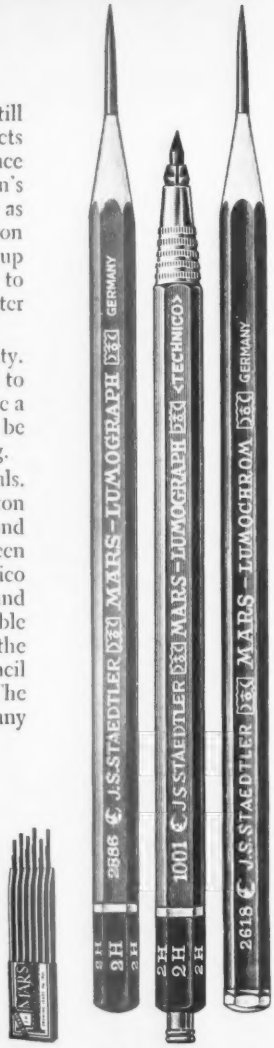


3 stages to space

The designs that will make news tomorrow are still in the "bright idea" stage today—or perhaps projects under development like this three-stage, two-man space ship. Drawn by Fred L. Wolff for Martin Caidin's "Worlds in Space," the rocket craft would start out as shown in the reverse drawing at left, shed its propulsion boosters in two stages as fuel is exhausted, and end up as the trim plane-like ship at right. Ship is planned to orbit a hundred miles above earth, return safely after one to two days.

No one knows what ideas will flower into reality. But it will be important in the future, as it is now, to use the best of tools when pencil and paper translate a dream into a project. And then, as now, there will be no finer tool than Mars—sketch to working drawing.

Mars has long been the standard of professionals. To the famous line of Mars-Technico push-button holders and leads, Mars-Lumograph pencils, and Tradition-Aquarell painting pencils, have recently been added these new products: the Mars Pocket-Technico for field use; the efficient Mars lead sharpener and "Draftsman's" Pencil Sharpener with the adjustable point-length feature; and — last but not least — the Mars-Lumochrom, the new colored *drafting* pencil which offers revolutionary drafting advantages. The fact that it blueprints perfectly is just one of its many important features.



The 2886 Mars-Lumograph drawing pencil, 19 degrees, EXEXB to 9H. The 1001 Mars-Technico push-button lead holder. 1904 Mars-Lumograph imported leads, 18 degrees, EXB to 9H. Mars-Lumochrom colored *drafting* pencil, 24 colors.

J.S. STAEDTLER, INC.
HACKENSACK, NEW JERSEY

at all good engineering and drawing material suppliers

• **Lear, Incorporated** . . . A new two-element lube oil and hydraulic pump for gas-turbine engines has been announced by the Lear-Romec Division . . . . The Board of Directors of the parent firm has elected two Senior Vice-Presidents—Philip E. Golde and A. G. Handschumacher. Robert H. Bloomberg was elected Assistant Secretary.

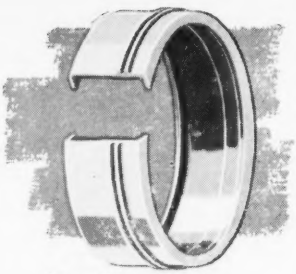
• **Lockheed Aircraft Corporation** has delivered the first of four specially modified Navy Neptune patrol bombers assigned to Admiral Byrd's current expedition to Antarctica, "Operation Deepfreeze." Equipment modifications include skis and conventional landing gear, engine preheaters, and a coat of bright orange paint for recognition against snowy background . . . . Assembly of the propjet Electra has begun. Tail sections at Bakersfield, Calif.; engines at Indianapolis; wing tips at Dallas, Tex.; and nacelles at San Diego, Calif., are being shipped to assembly points. Seven-foot-long ring-forged aluminum sections will be used in the Electra's keelson-gear-wing junction . . . . Australia's Qantas Empire Airways has taken delivery on its fourteenth Super Constellation and ordered two more Super G's . . . . Grading has begun at the Georgia Division's 140-acre tract where a modern engineering center will be constructed . . . . A recent test flight between Fort Worth, Tex., and Marietta, Ga., by the C-130 Hercules transport is reported to have set a speed record of 425 m.p.h. . . . A division engineer has patented an "outrigger" aerial delivery system said to absorb contact shock and prevent load tipping. Plastic bending "outrigger" arms absorb landing shock . . . . W. G. Myers has been appointed Director of Military Sales and R. I. Mitchell Military Sales Manager.

• **Loewy-Hydropress Division, Baldwin-Lima-Hamilton Corporation,** has designed, built, and installed the firing and launching platform for the earth satellite. The Project Vanguard site is at the Air Force Missile Test Center, Coca, Fla.

• **The Glenn L. Martin Company** has formed Martin International, a wholly owned subsidiary company which will explore and develop world markets for nuclear-powered electrical generating systems. George B. Shaw, a Martin Vice-President, has been appointed President of the new company . . . . John E. Parker has been elected to the Board of Directors.

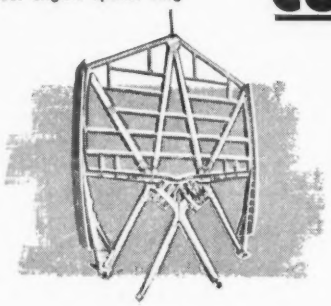
• **Norden-Ketay Corporation** has published a bulletin on its new three minute-size 23 synchros which enable design engineers to increase accuracy in control and data transmission systems and servomechanisms. *Bulletin No. 409* is available by writing Norden-Ketay Corporation, Commerce Road, Stamford, Conn.

• **Northrop Aircraft, Inc.,** has developed a new packaging method for handling and storing sensitive electronic components. The system consists of molded, reinforced plastic tote boxes, removable polyurethane cushion pads, and a flexible polyethylene box cover to protect vital missile parts from handling shock, vibrations, weather, or temperature changes and corrosion . . . . Northrop engineers have successfully applied a moving pickoff head to a new,

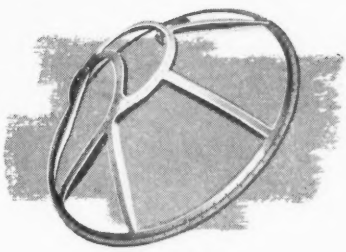


Jet engine spacer ring

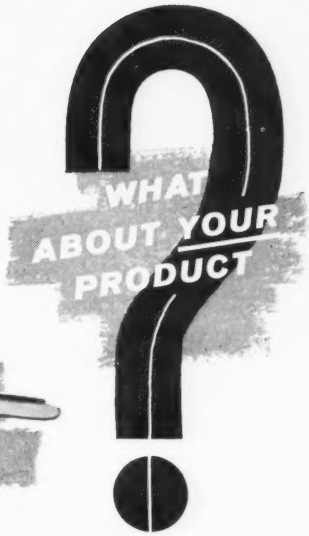
Save up to 70%
on material costs
CUT machining costs by 50%

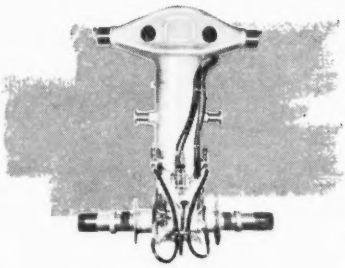


Bulkhead

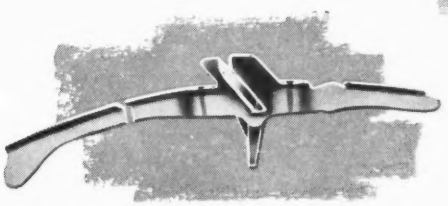


Bomber nose

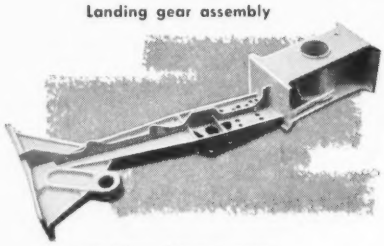




Landing gear assembly



Inboard strut for airframe assembly



Stabilizer hinge support

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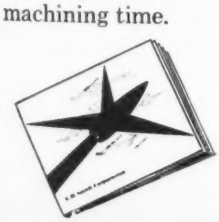
Engineered Designs for Optimum Structures

Put your complex components in the hands of A. O. Smith! Exclusive E.D.O.S. manufacturing process is faster than conventional methods . . . assures a stronger product . . . cuts your costs.

For example, a conventional titanium rough-forged jet engine ring, 17½″ O.D. x 5½″ wide, weighs 70 pounds — while its counterpart, an E.D.O.S. precision-forged, contour-rolled titanium ring, weighs but 20 pounds! Save 71% on material . . . 50% on machining time.

This remarkable metal- and work-saving process is ideal for titanium, steel and other heat-resistant alloys . . . may be the answer for fabricating your product. For further details about E.D.O.S., contact A. O. Smith Corporation, Milwaukee 1, Wisconsin.



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CORPORATION
MILWAUKEE 1, WISCONSIN

International Division: MILWAUKEE 1, WISCONSIN

medium-speed, digital computer. The mechanism makes it possible to record or read on 64 magnetic memory drum channels using only two pickoff heads . . . . John B. Ward has been named Director of the firm's extensive Reliability Program.

• **Pacific Scientific Aeroproducts,** which will move from Glendale, Calif., to Anaheim, has announced appointment of Howard H. Haglund to the newly created post of Director of Engineering.

• **Pan American World Airways, Inc.,** has opened a ticket office in Atlanta, Ga., at the Fulton National Bank Building, Marietta and Forsythe Streets . . . . Henry W. Beardsley, former Washington District Sales Manager, has been appointed U.S. Passenger Sales Manager.

• **The Parker Appliance Company** has produced a new "Ferulset" tool designed to aid in make-up of flareless-type tube fittings. Mounted in a vise, the tool expedites presetting of the fitting ferrule onto the metal tube. . . . *Tube Fabricating Equipment Catalog No. 1140,* covering Parker hand tools, tube cutters, flarers, benders, and also bench-mounted tools, has been published and is available at Parker distributors or from W. D. Wynant, Tube & Hose Fittings Division, Parker Appliance Co., 17325 Euclid Avenue, Cleveland.

• **Piasecki Aircraft Corporation** has acquired for $1.3 million the 330-acre plant, machinery, and other physical assets of the Aircraft Division of the Bellanca Corporation of New Castle, Del. The New Castle plant, fully equipped with aircraft manufacturing machinery in four brick buildings and high bay hangers, will add 258,000 sq.ft. to the firm's present facilities. The tract includes a private airport with a 3,500-ft. runway. Operation of the plant will be under the direction of James H. Manning who will be transferred from Piasecki headquarters in Philadelphia.

• **J. B. Rea Company, Inc.,** has announced the appointment of W. E. Staff, Jr., Applications Engineer.

• **Reaction Motors, Inc.,** and Olin Mathieson Chemical Corporation have announced the establishment of joint field liaison offices in Dayton, Ohio, and Los Angeles. Both companies are working jointly in the field of supersonic propulsion.

• **Republic Aviation Corporation** has begun a college-level training program for its engineering personnel. More than ten advanced aeronautical courses are offered without college credit and will be taught by qualified Republic engineers. Courses begun in January were Stress Analysis for Aircraft Designers, Instructor Training, Introduction to Power Plant Design, Aircraft Hydraulic Systems, Aircraft Electrical Systems, Electronics, Servomechanisms & Antenna Design, Stress Analysis, Introduction to Flight Control Systems, Drafting Procedures, and Apprentice Training Program for Draftsmen. Instruction will be on company time with a minimum of 3 hours per week allowed. Academic backround will be required only for certain advanced courses . . . . James Roye has been named Factory Manager at the Farmingdale, N.Y., plant. Also receiving promotions were George Cole, Chief Manufacturing Engineer; Eric Herold, General Superintendent of Experimental; James Craemer, Superintendent of Hangar and Assembly Plant; and Francis Coraggio, Superintendent of Production Hangars.

• **Ryan Aeronautical Company** has launched an extensive hiring program for an additional 1,300 employees to meet accelerating production demands . . . . Robert L. Clark, Works Manager of the firm, will assume full responsibility for direction of the Manufacturing Division.

• **Solar Aircraft Company** has named France Q. Wilson Manager of Turbine and Control Sales.

• **Sperry Gyroscope Company Division of Sperry Rand Corporation** has developed a new electronic engine analyzer with a 5-in. oscilloscope. The device will enable flight line personnel to detect and pinpoint possible ignition and vibration malfunctions in reciprocating engines.

• **Thompson Products, Inc.** . . . The Accessories Division has awarded lab assistant Jack Jones the firm's second highest suggestion award—$4,646—for uncovering a new buyer for the division's annual volume of 563,000 gal. of waste fuel—on his own time.

• **Trans World Airlines, Inc.,** has opened its new $2 million office building in Kansas City, Mo. It houses 700 finance, district sales, regional public relations, and secretarial department employees; has an indoor parking garage; and is crowned by

Precision-built instrument motor.
Radar voltage regulator gear motor.
HELP WANTED: A DEPENDABLE MOTOR TO DRIVE OUR PRODUCT
ABC MANUFACTURING CO.
Ruggedly constructed equipment motor.
Signal corps transmitter blower motor.

We Suggest You Consider The Qualifications of This Motor

Representative of the Lamb Electric Motors now in service driving many types of products, this motor:

First, was designed for the particular job to be done, assuring optimum product performance.

Second, was developed and manufactured by personnel having many years of experience in the small motor field.

Third, was *custom manufactured* on a volume basis.

For these and other reasons, use of a Lamb Electric Motor usually results in an improved product . . . *and lower overall costs.* May we demonstrate?

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The blue cold above the troposphere is simulated in a ground level laboratory.

Feet-on-the-ground engineers...at 60,000 feet

Research Engineers don't have to fly to the stratosphere to conduct high altitude tests at North American's Columbus Division. The bone-chilling conditions are simulated right here, in one of the laboratories of our completely equipped Engineering Department.

At the present time, the expanding work of this Department is creating unusual opportunities for you if you are an engineer with a career to make in the aviation industry. Facilities are among the finest anywhere. They include a fine new air-conditioned engineering building and 16 completely equipped laboratories, designed to enable creative engineers to carry out experiments, studies and development of their ideas.

The Columbus Division has prime responsibility for all North American Naval aircraft projects from concept through flight. Recognition is rapid for men who want to make their own way through their own ability. You should certainly investigate the opportunities here in your field.

PROMISING POSITIONS ARE OPEN IN EVERY FIELD:

Aerodynamicists, Thermodynamicists, Dynamicists, Stress Engineers, Structural Test Engineers, Flight Test Engineers, Mechanical and Structural Designers, Electrical and Electronic Engineers, Wind Tunnel Model Designers and Builders, Research and Development Engineers, Power Plant Engineers, Weight Engineers.

Write for the full story: Mr. J. H. Papin, Personnel Manager, Dept. 562-AER, North American's Columbus Division, Columbus 16, Ohio.

THE COLUMBUS DIVISION OF
NORTH AMERICAN AVIATION, INC.

a lighted, 35-ft. rocket ship on the highest point . . . . Carter L. Burgess, who resigned as Assistant Secretary of Defense, has been named President of TWA and will assume executive duties following completion of Government projects in which he is currently engaged.

• **Union Carbide and Carbon Corporation . . .** An 8-page illustrated booklet on "Columbia" activated carbon has been published by the National Carbon Company. Copies of this *Catalog S-6450* may be obtained from National Carbon Company, 1300 Lakeside Avenue, Cleveland.

• **United Air Lines, Inc.,** has a new electronic brain that can retain five million units of information. To be placed in service next fall, the device will memorize all flight reservations on the firm's entire system. It is reported to be the first of its kind in the transportation industry.

• **Vickers Incorporated . . .** The 97 guests who attended the firm's 1956 Transport Aircraft Hydraulic Conference represented all leading air lines of this country and six representatives of foreign countries. Four sessions were held during which technical papers were delivered . . . . R. J. Sullivan has been appointed Director of Quality Control.

• **Weber Aircraft Corporation** has appointed David H. Huribut Director of Industrial Relations.

• **Westinghouse Electric Corporation** has published a booklet of essential data on Reliatron receiving tubes for service technicians, amateurs, and engineers. Called *Westinghouse Ready Guide*, copies are available at Westinghouse Electronic Tube Division, Dept. T-286, Route 17, Elmira, N.Y.

• **Weston Electric Instrument Corporation** has added two models to its line of thermally fused metal film resistors (vamistors) . . . . J. R. Curley has been named Sales Manager for Vamistor Products. Others promoted are Kenneth C. Moulton, Manager of a new Los Angeles branch office; Edward B. Annett, Jr., District Sales Manager for the Cincinnati territory; and Dudley K. Bailey, District Sales Manager for the Buffalo territory.

IAS SECTIONS

Baltimore Section

A panel of four speakers discussed "Rocket Sled Vehicles and Test Operation" at the November 8 meeting at Aircraft Armaments, Inc., Cockeysville, Md.

Speakers were Paul E. Fisher, Head, Range Control Section, Supersonic Track Division, Naval Ordnance Test Station; Lt. Charles E. Wilson, Jr., Chief, WDD Projects Division, Holloman Air Development Center; Hugh Thompson, Project Technical Director, Project SMART, Coleman Engineering Co., Inc.; and Richard A. Hirsch, Project Engineer, Aircraft Armaments, Inc.

A description of physical details of rocket sleds and high-speed tracks was presented, and instrumentation techniques required to record action and test results were outlined.

Techniques included telemetering, photography, accelerometers, displacement sensors, and time correlation. High-speed track tests performed included ejection, flutter, and personnel equipment studies. Slides and films depicting these test studies were shown.

Besides operational aspects, Mr. Hirsch presented design details leading to the contruction of a rocket sled.

R. G. CLANTON, *Secretary*

A panel of four speakers discussed "Rocket Sled Vehicles and Test Operation" at a Baltimore Section meeting. Speakers shown are: Richard A. Hirsch, Project Engineer, Aircraft Armaments, Inc.; Paul E. Fisher, Range Control Section Head, Naval Ordnance Test Station, Supersonic Track Division; Richard W. Sanford, IAS Baltimore Section Chairman; Hugh Thompson, Project SMART Technical Director, Coleman Engineering Co.; and Lt. Charles E. Wilson, Jr., Chief, WDD Projects Division, Holloman Air Development Center.

Absolute Capability Theory

Chicago Section

Captain Norval R. Richardson, USN, spoke on "Absolute Capability—Key to Survival in the Thermonuclear Age" before 125 members and guests on November 14 at the Glenview Naval Air Station. Captain Richardson is Nuclear Aircraft Program Director for BuAer and Deputy Director, Aircraft Reactor Branch, Atomic Energy Commission.

The absolute capability theory, originated and developed by Captain Richardson, means that we as a nation must be able to retaliate and incapacitate any power which attacks our country before we ourselves are destroyed.

He said its effectiveness depends on how well equipped our Armed Services are to rise to absolute capability. No one Service can do the job. All must mutually support each other because each has its own unique problems.

The Air Force must have aircraft in the air or ready to take off at all times to provide protection for the Strategic Air Command bases, rather than build more bases which, in the event of an attack, would involve a greater number of civilians.

He said development of a nuclear-powered weapon system is being explored by the Services today so that, in effect, an air base in the air can be established.

Also important is study of the sea, of forcing possible combat to be fought over the seas, because 0.7 of the earth is water, and land mass advantage is not on our side.

The sea appears to be an ideal base from which to deliver retaliatory weapons. He said the problem is, " . . . Can the U.S. Navy deliver a sufficiency of weapons on the enemy from the seas?" Submarines, aircraft carriers, and missile launching ships would provide highly mobile bases from which weapons could be launched. But there is no perfect system. The lowest cost system which will guarantee absolute capability is still to be determined.

Nuclear-powered aircraft will have no limitations on range versus speed relationship as we know it today, he said. Limitation here will depend upon the amount of radiation a human being can absorb. Aircraft of this type could roam the world at will and could be supplied at either land bases or from ships at sea.

Nuclear propulsion units are designed around a simple concept, but high temperatures and other factors prohibit building such a unit for an aircraft.

Members engaged in an active discussion period after the talk.

R. F. HUNTER, *Secretary*

Cleveland-Akron Section

The place of the late Robert J. Woods of Bell Aircraft Corporation, scheduled to speak on "VTOL Aircraft and Convertiplanes," was taken by Joseph Platt,

In Engineering the

BEST OPPORTUNITIES

are in

AVIATION.

In Aviation the

BEST OPPORTUNITIES

are at

SENIOR TELEMETRY ENGINEER

Capable of planning and monitoring requirements of telemetering problems associated with missiles programs.

SENIOR ENGINEER

Analog Computers

Should be thoroughly familiar with up-to-date analog equipment and methods; capable of planning simulated programs involving electronic analog methods and equipment.

ENGINEER and SENIOR ENGINEER

Operations Research

Should be experienced in applied methods, either military requirements or market analysis.

SENIOR DESIGN ENGINEER

Guidance Systems Design

Capable of designing and evaluating for complex guidance systems and techniques as used in advanced missiles systems. Experience in electronics, inertia, radio command, infra-red forms of guidance equipment desirable.

ENGINEER and SENIOR ENGINEER

RH and Antenna Design

Experienced in UHF and microwave techniques and antenna design.

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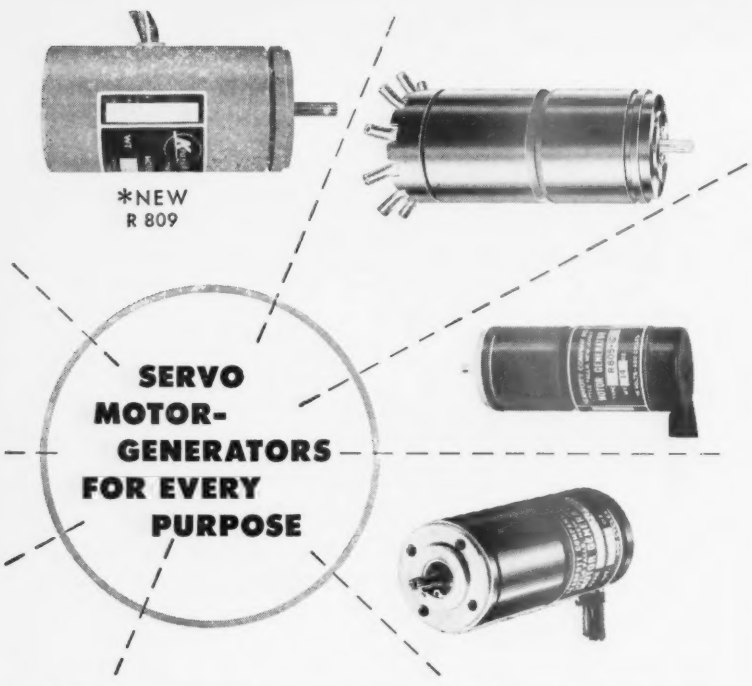

Kearfott Servo Motor-Generators are characterized by low rotor inertia, low time constants and high stall torque. Motor-Generator combinations provide ½ to 3.1 volts per 1000 R.P.M. with an extremely linear output over a speed range of 0—3600 R.P.M. and useful output up to 10,000 R.P.M.

**New Size 11 low cost, Servo Motor-Damping Generator Type R 809.*

CHARACTERISTICS				
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	STALL TORQUE	NO LOAD SPEED	OUTPUT FUND. NULL	LINEARITY
DAMPING				
SIZE 10	.35 OZ. IN.	6000	21/1	.5%
SIZE 10	.30 OZ. IN.	8500	23/1	.5%
NEW R 809	.63 OZ. IN.	5900	25/1	.5%
SIZE 15	1.5 OZ. IN.	5000	25/1	.5%
SIZE 18	2.4 OZ. IN.	5000	25/1	.5%
SIZE 18	3.0 OZ. IN.	9600	23/1	.5%
RATE				
SIZE 15	.45 OZ. IN.	10,500	170/1	.5%
SIZE 15	1.5 OZ. IN.	4700	350/1	.2%
SIZE 18	2.4 OZ. IN.	4700	350/1	.2%
SIZE 18	3.0 OZ. IN.	8400	350/1	.2%
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SIZE 15	.70 OZ. IN.	6300	400/1	.1%
SIZE 15	1.25 OZ. IN.	4500	400/1	.1%
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SIZE 18	2.4 OZ. IN.	5200	333/1	.06%
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Chief of Design, Aerodynamics Section, Wright Air Development Center. Mr. Platt spoke on the same subject at the November 20 meeting.

In charge of USAF boundary-layer programs, Mr. Platt has been working in the field of high-speed aerodynamics, stall characteristics, air loads, and high lifting devices for several years.

He presented a summary of design considerations, current developments, and problems of VTOL and STOL aircraft. Aircraft discussed included jet-powered tail sitters, propeller-powered tail sitters, tilted duct fan airplanes, tilted propeller arrangements, deflected slipstream aircraft, tilted wing aircraft, helicopters, convertiplanes, conventional STOL aircraft with larger propeller, leading-edge slots and boundary-layer control, high-lift flap boundary-layer control aircraft, boundary-layer control on complete aircraft, jet flaps, and others. A film of McDonnell Aircraft Corporation's convertiplane was shown.

Before the dinner meeting members toured the General Tire and Rubber Company plant.

JOHN C. EVVARD, *Secretary*

Dayton Section

Frank N. Piasecki, President of Piasecki Aircraft Corporation, spoke on "Steep Gradient Aircraft" at the November 15 meeting.

Mr. Piasecki outlined basic differences between members of the steep gradient aircraft family. He said high-lift fixed-wing machines, rotary-wing aircraft, and pure "propulsion supported" craft (jet risers) have in common a capacity for vertical or near-vertical flight. However, they differ in functional efficiency.

Where completely vertical ascent and descent are needed, the helicopter works best. But, where high-speed performance is required, the helicopter is unsuitable. This gap is bridged by convertible aircraft containing rotary and fixed wings and separate propulsion systems.

Mr. Piasecki showed movies of steep gradient aircraft which he had taken at the Farnborough Air Show in England.

▶ "Design Philosophy of the Convair 880 Jet Transport" was the subject of a talk by A. D. Riedler before 125 members and guests at the October meeting. Mr. Riedler is Design Specialist at Convair, A Division of General Dynamics Corporation.

He spoke about performance of the medium-range jet and showed color slides. Pay load for the 880 is 25,000 lbs., range 3,000 nautical miles, and normal take-off weight for a typical flight is about 158,500 lbs., he said. A runway length of 6,850 ft. would be needed for this take-off.

Direct operating costs for first-class configuration of the 80-passenger, swept-wing air liner will be between $1.45 and $1.55 per seat-mile for ranges of 1,500 nautical miles or more. Delivery to TWA and Delta air lines is scheduled for late 1959.

W. E. STANGER, *Secretary*

Cameron Split-Die Forgings

are different – they are made possible by something new in the metal-working industries. Intricate ferrous forgings with internal as well as external contours are being mass-produced. These near-final shapes with greatly improved grain structures are creating a new concept in the design and use of forgings.

Cameron's split-die forgings offer a variety of shapes and sizes (200 lbs. to 5,000 lbs.) in alloys to meet the extreme demands of today. They may be supplied as forged, rough machined, or finish machined, ready to save money on final operations. It is now possible to take advantage of the many benefits offered by high grade alloy ferrous* forgings in applications never before possible. Investigate these advantages. Write or call...

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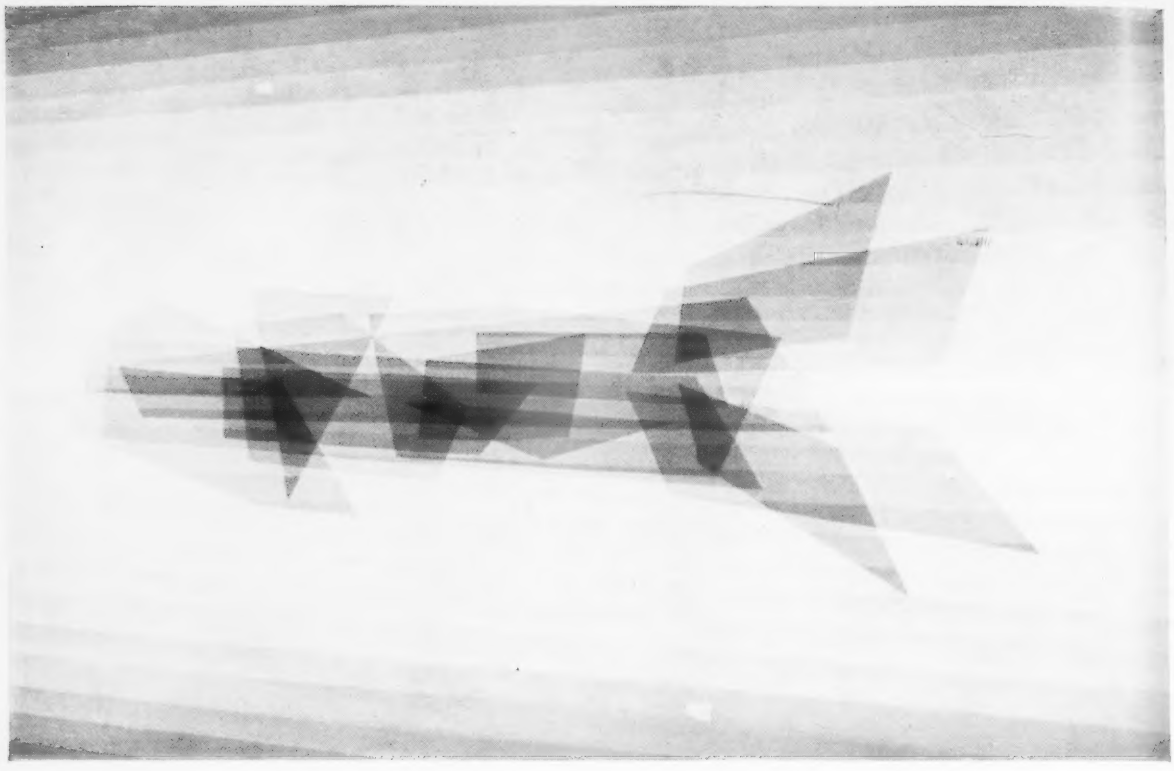

"ROCKETS", one of a series of paintings by Simpson-Middleman, a team of artists with the rare ability to translate scientific fact into creative imagery. Here, the rocket's blast and its guiding beam are thought of as a single stream of light through the center. Darks and lights of definite shape in a weak visual vector field are relied on to suggest the "wobble" caused by the acts of the servo-mechanisms in making their adjustments. Painting courtesy John Heller Gallery, Inc.

Invitation to sky-high adventure

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Drop a note now to John C. Sanders, Engineering Personnel Administrator, Boeing Airplane Company, Department A-60, Seattle 24, Washington.

BOEING

Participants in the International Aircraft Symposium at the Atlanta Section November meeting are: *(sitting)* Carl Bronn, Norway; Olle Olsson, Sweden; Peter Fielding, England; Peter Hulsebos, Holland; and *(standing)* Section Vice-Chairman C. F. Friend; Gordon Forbes, England; Wilfred Garrard, England; Jys Ruys, Holland; Willi Jacobs, Germany; Nils-Olof Olsten, Sweden; and F. B. Johnson.

Niagara Frontier Section

The November 14 meeting, at which the late Robert J. Woods was to have spoken on "Convertiplane and Other VTOL Aircraft," was canceled out of respect to Mr. Woods.

Officers expressed sympathy on behalf of the Section and scheduled a meeting for January 9.

RONAL B. CRISMAN, *Secretary*

St. Louis Section

"Communication and Navigation Techniques of Interplanetary Travel" was the subject of a talk given by Peter A. Castruccio, Missile Sub-Systems Advisory Engineer at Westinghouse Electric Corporation's Air Arm Division.

He said space offers the ideal medium through which electromagnetic waves may travel, free of bending, deviation, and attenuation effects found in atmosphere. He outlined potential applications of electronics to space navigation, communication, and anticollision techniques and discussed problems involved in each field.

Dr. Castruccio was of the opinion that electronic developments within the next 20 years should make feasible communications within the solar system. Equipment and techniques could be developed for a range of 45 quadrillion miles or 8 light years by 1970. Theoretically this would allow communication with the nearest stars, but practically such an experiment would have dubious effects since 8 years would be required to send and receive a message. A discussion period followed the talk.

▶ The Section's aircraft automatic control specialists met October 16 to hear a talk by H. C. Rechtien, Jr., F4H Control Dynamics Group Leader at McDonnell Aircraft Corporation.

His talk included an introduction to closed-loop control systems, definitions used in automatic control, a brief history of developments in the field, current status of automatic control in fighter aircraft, and an indication of future developments.

▶ The Section's Civic Committee and McDonnell Personnel and Public Relations departments are sponsoring evening tours through the McDonnell plant. Tours are part of the IAS objective of interesting young people in aeronautical engineering and of McDonnell's good neighbor policy.

The Section student paper competition is open to undergraduates of engineering colleges in the following states: Arkansas, Colorado, Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, Oklahoma, Ohio, North and South Dakota, and Wisconsin. Papers must be submitted by March 15. Announcement of winners will be made April 12. Prizes totaling $300 will be given at an awards dinner April 25.

San Francisco Section

Walter G. Vincenti, Aeronautical Research Engineer at NACA Ames Laboratory, spoke on "Reflections on the Aerodynamic Research Scene in England and on the Continent" at this Section's October meeting.

His informal remarks centered on his experience at Cambridge University, where he spent 9 months of study, and on visits to educational and research establishments in other European countries. Mr. Vincenti had spent a year abroad as recipient of the Rockefeller Public Service Award.

He gave brief accounts of the aerodynamic facilities and current research projects at university and government laboratories in France, Germany, The Netherlands, Switzerland, Italy, and Sweden.

The following members were nominated for office: Russell Robinson, Chairman; Stan Moy, Vice-Chairman; Jack Bert, Treasurer; Bob Crane, Secretary; and Smith De France, Area Counselor. Some 60 members attended the meeting.

JACK BERT, *Secretary*

Texas Section

R. J. Volluz, Chief, Supersonic Wind Tunnel, Ordnance Aerophysics Laboratory, discussed "Supersonic Wind-Tunnel Testing" at the Section's November specialist meeting.

He described OAL facilities for testing both aerodynamic shapes and engines. Problems of obtaining and reducing large quantities of data in extremely short periods of time were discussed. Examples of typical data were shown, and data accuracy, repeatability, and significance were explained. Some 60 engineers engaged in a discussion period after the talk.

A. T. CLEMEN, *Secretary*

Tulsa Section

"Flight Operation Characteristics of the Boeing 707" was the subject of a talk given by Joseph F. Sutter at the November 12 meeting. Mr. Sutter is Unit Chief, Aerodynamics Unit, Transport Division of Boeing Airplane Company.

Wayne W. Parrish *(left)*, Editor and Publisher of *American Aviation*, was introduced to 150 members of the Texas Section by Chairman Robert J. Patton *(center)*, and H. W. Hinckley, Assistant Chief Engineer at Convair, A Division of General Dynamics Corporation. Mr. Parrish told of impressions he gathered on a recent trip to Russia.

Controlling 350,000 pounds at 650 miles per hour

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THE Boeing B-52 Stratofortress is designed to fly high, fast and far. The B-52 B model weighs 350,000 pounds, flys at speeds of 650 miles per hour and at altitudes of more than 50,000 feet.

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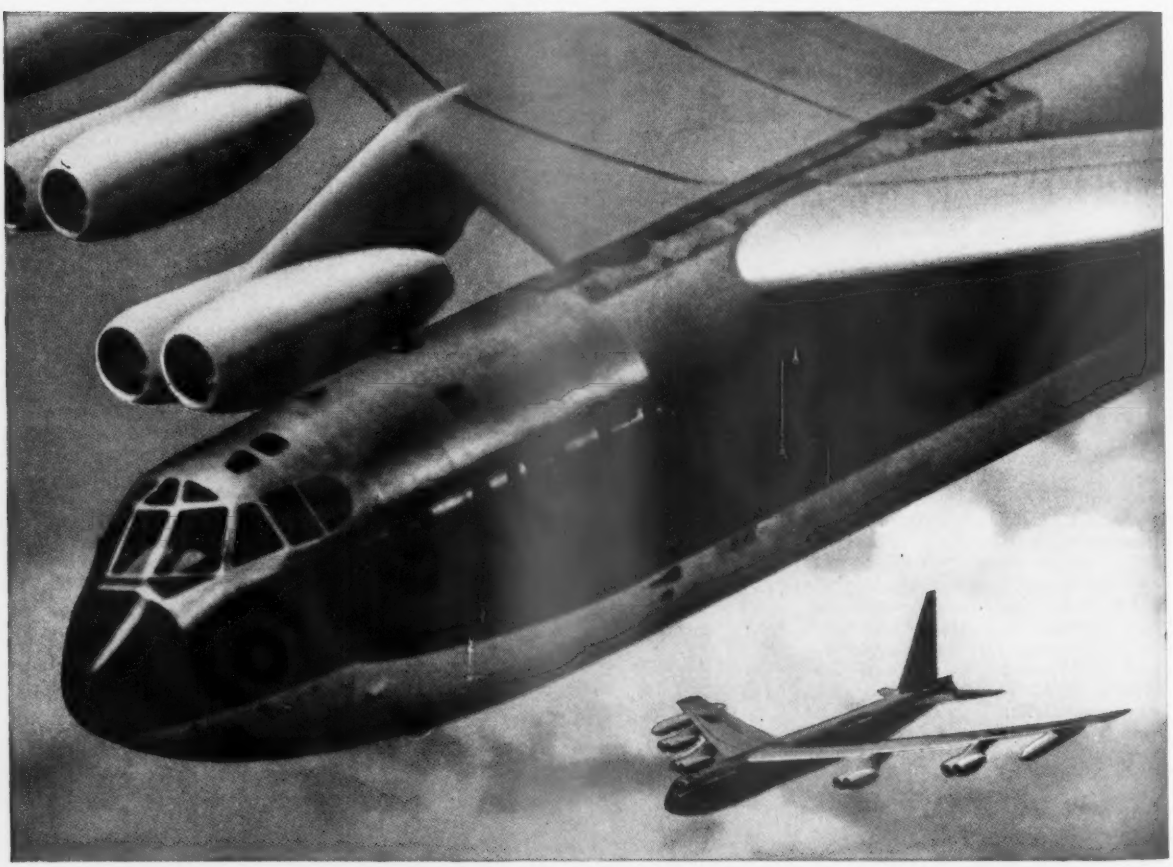
Boeing B-52 Stratofortress with capabilities for multiple strategic roles—conventional and nuclear weapons delivery and photographic reconnaissance.



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UNITED STATES STEEL

James R. Gannett, Project Pilot—707, presented the pilot's point of view.

Mr. Sutter described the design and some of the operational features of the 707. Using color slides, he compared flight controls and operational characteristics of the 707 with piston-powered aircraft. He stressed some of the more novel features in these categories.

Mr. Gannett showed movies of the 707 flight test, described its flying characteristics, and told of its test performance.

C. K. BARTON, *Secretary*

Washington Section

IAS President Edward R. Sharp introduced I. Irving Pinkel, Chief of Flight Problems Division, NACA Lewis Flight Propulsion Laboratory, who spoke on "NACA Crash Survival Research" at the November 13 meeting. Dr. Sharp was Honorary Chairman of the meeting.

Mr. Pinkel interpreted the NACA research program with the aid of slides and color movies. He stressed cause and prevention of engine-ignited fires associated with jet aircraft crashes.

GEORGE T. HAYES, *Secretary*

Wichita Section

Chairman Jerry Gerteis introduced new officers at the November 7 meeting. Officers besides Mr. Gerteis are San Hinton, Vice-Chairman; Edward J. Sullivan, Secretary; and Pink Jackson, Treasurer.

Marvis Marks, Chief of Rotor Research, McDonnell Aircraft Corporation, spoke

Travel Arrangements

IAS-RAeS Conference
London and Folkestone
Sept. 1–16, 1957

Arrangements have been made with "The Travel Center of Manhasset" to accomplish all travel and hotel reservations for the delegates and their wives. This travel bureau handles all arrangements on a "personal" basis. The bureau has now obtained commitments from air lines, steam ship companies, and hotels to assure the availability of accommodations. The air-line commitments include group arrangements on TWA and Pan American flights which will allow delegates to travel overseas together.

Special arrangements also have been made by the travel bureau with American Express, Thomas Cook & Son, and Ask Mr. Foster for preconvention and postconvention tours of Europe by the delegates—individually or in groups.

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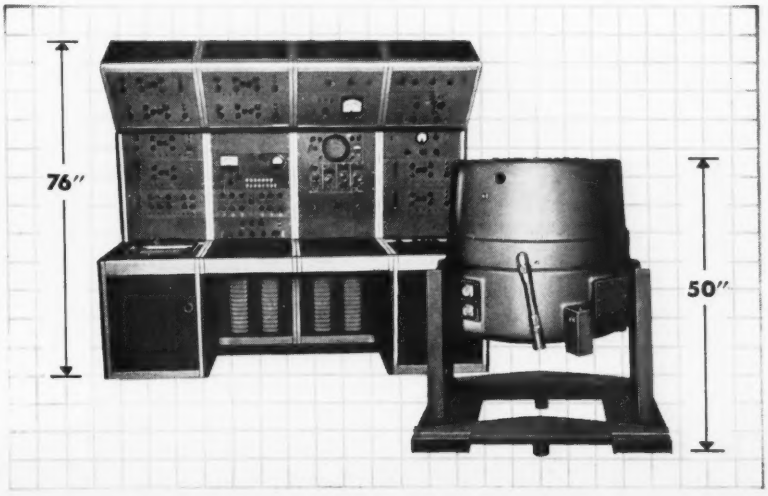


on "The McDonnell XV-1 Convertiplane." He reviewed design and development including problems encountered and showed a color movie of the convertiplane. Slides were used in an explanation of the rotor system and to show performance characteristics as a helicopter, autogiro, and conventional airplane. A discussion period followed the lecture.

Guests included Charles Seibel, President of the American Helicopter Society, and E. W. Robischon, Manager, IAS Western Region.

EDWARD J. SULLIVAN, *Secretary*

STUDENT BRANCHES

Agricultural & Mechanical College of Texas

Chairman Harless R. Benthul introduced T. E. Allen, Supervisor of Wing and Surfaces Design at Chance Vought Aircraft, Incorporated, to 65 members and guests at the October 25 meeting.

Mr. Allen spoke on aircraft design and outlined groups in an engineering department.

About 1.25 million man-hours go into designing and building a prototype aircraft, he said. Design of the wing presents the greatest difficulties. In thin wings of supersonic planes there are problems of aileron reversal and flutter due to small torque boxes and thin-wing skin. Naval planes with thin wings need special devices to give the lift needed for carrier operations. This can be supplied with leading-edge droop, slots, and varied angle of attack.

Mr. Allen said extruded members now being used in wings are still in the experimental stage. Research, development, and design detail are important, and engineers with imagination are in demand.

After the talk, the film *Project One Gram*, produced by Chance Vought, was shown. It depicted preparations by the firm and the U.S. Navy in winning the Thompson Trophy at the National Air Show. A Chance Vought Crusader, using fuel cooled before loading, flew more than 1,000 m.p.h., breaking the 1955 record. A discussion period followed the film.

▶ *The Supersonic Wedge*, a film made by Convair, A Division of General Dynamics Corporation, was seen by 30 members at the October 23 meeting.

Convair advancements in delta wing design were depicted. Delta wing progress was shown in the XF-92A, the firm's first delta wing plane; the Sea Dart, first delta wing to break the sound barrier; the VTOL XFY-1 Pogo Stick; and the XF-102A, supersonic fighter now in USAF service.

▶ J. E. Woolfe, of the College Mechanical Engineering Department, spoke on "Expansion in the Aircraft Industry" at the October 9 meeting.

Dr. Woolfe said that, before World War II, the main areas of aeronautical engineering were aerodynamics and mechanics of flight, structural analysis, and power plant. As airplanes became more complicated, new fields emerged—aeroelasticity, internal aerodynamics, and guidance and control. Aircraft design in a large company requires the teamwork of specialists as a result. The industry now looks for young engineers not only with ability in their field but also with leadership qualities necessary for team effort and results, he said.

LAWRENCE L. PATTON
Secretary

Boston University

Harold Soule, an Aerodynamicist for Sylvania Electric Company, spoke on "Missile Systems" before 40 Branch members on November 13.

Mr. Soule's talk centered upon development of the missile and its guidance network through the concept of research analysis, the design and test of many various units, evaluation of each unit, and finally design of a compromise system that best meets specifications.

He said the role of the aerodynamicist in missile development presents difficult problems such as consideration of angle of attack due to complex and unpredictable vortex formation. At low angles of attack the vortex action is mathematically predictable, but, at high angles, wind tunnels and other research apparatus are needed to obtain design data.

He commended NACA and university research programs on vortex problems. He suggested the study of vorticity as a subject for a thesis or graduate study, pointing out that it is a challenge for all aerodynamicists.

FRANK H. NICHOLS, *Secretary*

The Catholic University of America

A talk on naval airships was presented by a member of the Navy Bureau of Aeronautics at the November 15 meeting.

Slides and movies were shown, and samples of airship material—recently developed dacron and nylon fabric—were passed among members. After the talk a discussion period was held.

James McGrath, IEC representative, reported on the IEC meeting and explained several aims of the organization.

CHARLES B. SPENCER, *Secretary*

Georgia Institute of Technology

Two movies, *Horizon Unlimited* and a film on the French skid fighter, were shown at the November 12 meeting.

EUGENE KNOX, *Secretary*

Iowa State College

Fred Stuve, Professor in the Aeronautical Engineering Department of the College, spoke at the November 14 meeting.

He told of his work during the summer on an integral fuselage fuel tank for the Chance Vought Crusader and explained some of the problems connected with strength requirements and leakage prevention.

MARVIN BAXENDALE, *Secretary*

Kent State University

Films on the Martin Matador, B-52, and F-104 radar picket plane and on SAC bombing practice were shown at the November 14 meeting.

Some members attended the IAS-sponsored tour of the General Tire and Rubber Company plant and a social hour and lecture at Akron's University Club November 20.

Two members scheduled to attend the International Meeting to be held by the Canadian Aeronautical Institute and the IAS in Toronto were Don Straley and Bob Andrews. Both attended last year's meeting in Ottawa and were the only student members present. Their plans were to fly to Toronto in Mr. Straley's private plane. The Branch appropriated $15 to defray expenses.

Committees were appointed to prepare a brochure on the aviation technology program, prepare a newsletter about graduates, and nominate officers for coming elections.

ROBERT D. FENNING, *Secretary*

Mississippi State College

R. D. Clark, of the Operations Analysis Department, McDonnell Aircraft Corporation, spoke on "The Kinds of People that Design Aerial Weapons Systems" at the November 8 meeting.

Dr. Clark began by citing some of the many problems encountered in the design of a new aerial weapons system and the skills and knowledge of various fields needed to overcome them. The task of acquiring this knowledge and skill is too much for any one man, therefore a team of specialists is needed. He mentioned as an example of this diversity the designers in his department—their education, experience, and contributions.

In conclusion, Dr. Clark said the man needed to design an aerial weapons system must be an intelligent, curious man with a technical education and the ability to communicate and sell his ideas.

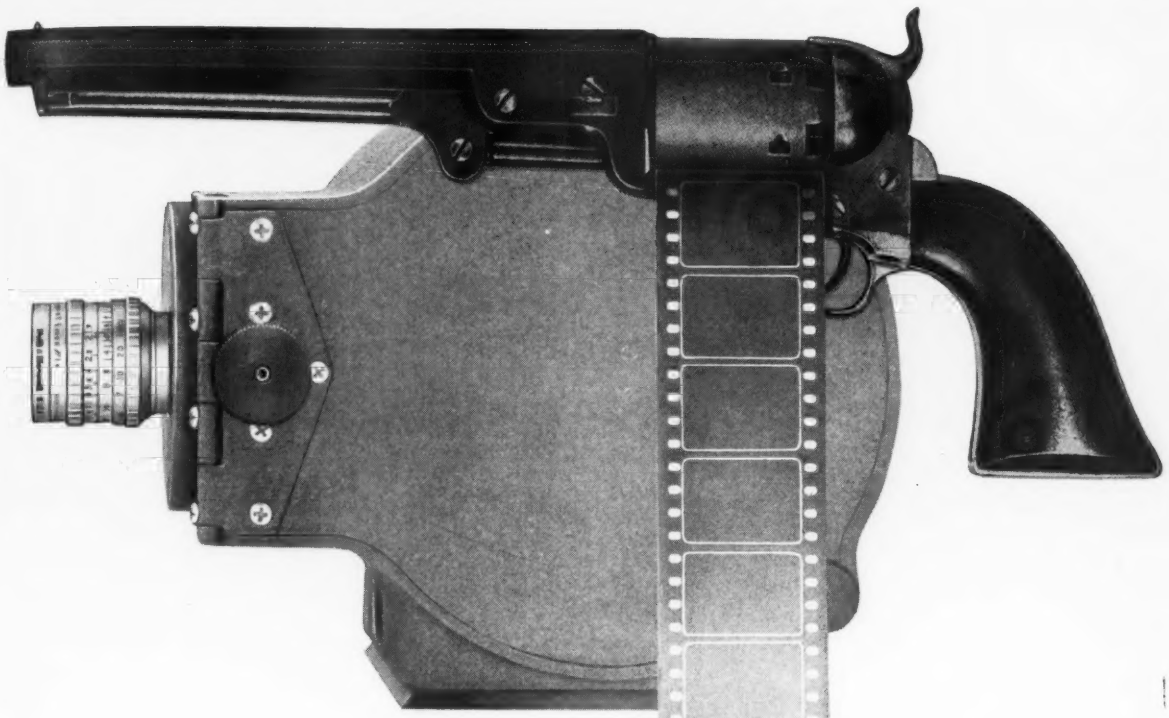
The Branch Chairman announced that a film, *Engineering for Tomorrow*, courtesy of North American Aviation, Inc., would be shown at the next meeting.

HUGH PARKS, JR., *Secretary*

Northrop Aeronautical Institute

Late October and November meetings included talks by an astronomer and an aerodynamicist and the installation of officers.

Dinsmore Alter, Director of Griffith Park Observatory in Los Angeles, discussed the moon's surface and explained environmental conditions an explorer may expect to find there. Slides taken through the Mt. Wilson telescope were shown.



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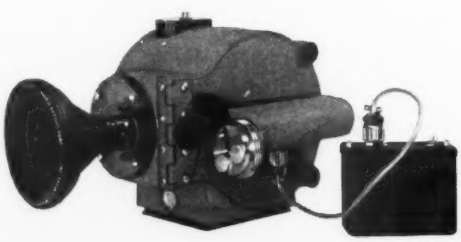

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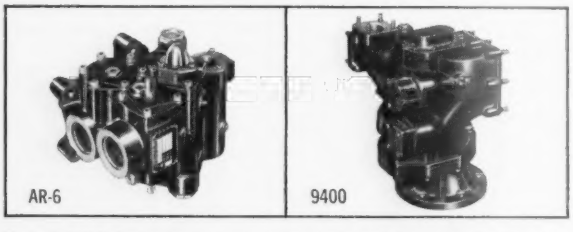

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Dr. Alter expressed the opinion that most surface irregularities were due to volcanic eruptions and settling. He said the moon is strictly for women. A 100-lb. woman can equal the work of a 150-lb. man, will cost less to send to the moon, and less to keep there.

Allan Pope, Director of the Aerodynamics Division of Sandia Corporation, spoke on atomic weapons. He described precautions taken by observers at bomb test sites and explained effects of atmospheric conditions on shock waves created by the bomb. He showed a film on an A-bomb test at Eniwetok Atoll.

Branch officers installed were Ira Holt, Chairman; William Ketchum, Vice-Chairman; Rodney Hutchinson, Recording Secretary; Donald Lesney, Treasurer; and James, Tipton Correspondence Secretary.

A committee was created to design and construct a wind tunnel. Other committees are bringing up to date old by-laws, arranging a field trip, and publicizing the IAS Student Conference.

JAMES TIPTON
Correspondence Secretary

Ohio State University

James L. Detweiler, Research Group Engineer at Lockheed Aircraft Corporation, compared turboprop and turbojet transports at the November 7 meeting—in which the Branch was joined by students of the SAE and ASME branches.

Mr. Detweiler showed slides and discussed points to be weighed in choosing a future commercial airplane. He said consideration must be given to required runway length, operating cost per seat mile, block time, profit and loss versus load factor, and operational areas of current design types.

Students participated in a brief discussion after the talk.

GORDON A. TAYLOR, *Secretary*

The Pennsylvania State University

G. B. Edelen of The Glenn L. Martin Company spoke on "Earth Satellite-Vanguard Research Vehicle" before a joint meeting of this Branch and a newly formed American Rocket Society branch on November 29.

Mr. Edelen described the rocket construction of the satellite and explained the purpose of Project Vanguard. With slides he showed the trajectory to be followed and planned operational precision of the experiment. Technical problems facing the project were outlined, and a discussion period was held.

An inspection tour of Piper Aircraft Corporation facilities at Lock Haven, Pa., was discussed.

ROBERT L. WASACAVAGE, *Secretary*

Rensselaer Polytechnic Institute

The November 14 meeting featured a talk on "Structural Problems of High-Speed Flight" given by Wilfred H. Dukes, Head of Advanced Design, Structures Section, Bell Aircraft Corporation.

Mr. Dukes centered his talk on the effects of heat on structural material. Heat

may reduce structure strength and stiffness and result in buckling and creep, he said. Problems which arise include oxidation and reverse heat treatment at high temperatures, lag between heating of skin and heating of webs, stringers, and spars.

Ways of reducing these problems were outlined. Foremost is the development of new materials which retain more of their strength at high temperatures. Also, different methods of construction are employed. Sandwich honeycomb construction is valuable because it has high compressive strength and conducts heat better. The use of corrugated webs permits free expansion and contraction. Surfaces are cooled by water circulating through pipes and ejected as steam.

ROBERT E. KELLY, *Secretary-Treasurer*

San Diego State College

A description of the General Dynamics Corporation, Convair Division, supersonic wind tunnel was given at the November 13 meeting.

A Convair representative told members his firm is building a structure that will be a typical induced air draft wind tunnel. Wind will be produced by a difference in pressures at either end. The head of the tunnel will contain the high-pressure chamber.

An 8,000-hp. motor is necessary to compress air to make a multiple Mach Number wind, the representative said. Cost of electrical power to run this motor will be $13,000 a month.

Instrumentation was described, and differences in heat levels inside and outside the tunnel were explained. Also mentioned were changes necessary to transform a subsonic tunnel to supersonic.

MICHAEL D. CHILCOTE, *Secretary*

Stevens Institute of Technology

A film, *The Jet Age*, was shown at the November 28 meeting.

High school students of the metropolitan area were invited to an Open House at the November 14 meeting. An IAS exhibit included literature, model planes, and photographs of latest aircraft. Visiting students asked Branch members many questions at the meeting.

At the first organizational meeting on November 7, 24 new students joined the Branch and were introduced to its activities and benefits by Chairman Edward Griffith. They also were introduced to the AERONAUTICAL ENGINEERING REVIEW and other IAS publications.

GERARD FRIDSMA, *Secretary*

University of Florida

Two films, one on the Northrop F-89 Scorpion and another from the Navy Department on take-offs with JATO assist, were shown at the November 19 meeting.

Lists of prospective members in sophomore and freshman classes were distributed to each Branch member for recruiting purposes.

Frank Castellon, *pro tem* Engineering Fair Chairman, reported on the fair committee's first meeting. Pictures of Fair Queen candidates will be posted before balloting begins. Some 50 companies were contacted with requests for exhibits. Two positive replies already have been received.

Bill Beims reported on BEC proceedings. Shirley Ogram was elected unanimously as Junior BEC representative for the Branch.

Ed Blanchette spoke briefly about his summer job at the Jacksonville NAS Overhaul and Repair Department at the November 4 meeting. He said he obtained the job after a civil service exam and that his work was on the F8U Crusader and DC-3 transports.

A Lockheed progress report film on the C-130 turboprop was shown.

JOHN DAVID ANDERSON
Recording Secretary

University of Illinois

Robert S. Chubb, a member of Operations Research Group at Lockheed Aircraft Corporation's Georgia Division, spoke on "Engineering Problems Solved Through Operations Research" at the November 7 meeting.

Mr. Chubb explained the need and function of operations research. Variety of power plants, weapons, and targets has added to the complexity of designing modern aircraft for specific missions, he said. Designing a plane which was never used was a costly venture in the past, but through operations research, which takes all pertinent and available factors and reduces the problem to the best design, high cost can be avoided.

He showed how his organization digested data to arrive at a final design in a military and civilian airplane. Military data include pay load, distribution of targets, size of aircraft, possible power plants, and speculation concerning future enemy aircraft, enemy evasive measures, and similar items. Civilian data include sway of passenger likes and dislikes and possible profits.

A discussion period followed the talk, which was heard by 75 members. Fred Breuer was elected Vice-Chairman of the Branch.

EUGENE G. HILL, *Secretary*

U.S. Naval Postgraduate School

Robert Schairer of the Development Planning Division of Lockheed Aircraft Corporation spoke on "Technical Aspects of Space Travel" before 30 students and guests at the November 14 meeting. Dr. Schairer's lecture was classified "secret."

GEORGE E. JESSEN, *Secretary*

MEMBERS ELECTED

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the Review.

Elected to Associate Fellow Grade

Hatton, George A., M.S. in Ae.E., Capt., USN; Plans & Progress Officer for R&D, BuAer.

Olson, Elden H., B.S. in Ae.E., Dir.—Aero. Engrg., Minneapolis-Honeywell Regulator Co.

Westfall, John R., B. of Ae.E., Div. Exec., NACA (Langley Field).

Transferred to Associate Fellow Grade

Brown, Albert D., B.S., Chief Systems Engr. Lockheed Aircraft Corp. (Marietta).

Chesley, George B., B.S., Proj. Engr., Sikorsky Aircraft Div., United Aircraft Corp.

Frick, Charles W., B.S. in M.E., Chief-Appl. Research, Convair Div. (San Diego), General Dynamics Corp.

Jablecki, Leon S., Dr. Sci., Lt. Col., USAF; Deputy Chief, Aero. and Propulsion Div. (Baltimore).

Kupelian, Vahey S., B. in M.E., Dir.—Engrg., Naval Ordnance Experimental Unit (Wash., D.C.).

Paine, Joseph P., S.B. in Ae.E., The Glenn L. Martin Co.

Shaw, Spencer L., B. of Naval Sci., Chief—Strength Sect., Douglas Aircraft Co., Inc. (El Segundo).

Sheehan, William F., M. of Ae.E., Engrg. Sect. Head, Sperry Gyroscope Co. Div., Sperry Rand Corp. (Pt. Mugu).

Uhl, Edward G., B.S. in Engrg. Physics, V-P—Operations, The Glenn L. Martin Co.

Elected to MEMBER Grade

Acharya, Y. V. G., Ph.D., Sr. Scientist, Ministry of Defence, Govt. of India.

Arnberg, Benjamin T., M.S. in M.E., Assoc. Prof., Univ. of Colorado.

Barnett, Clyde H., Jr., B. of E.E., Lt. Col., USAF; Asst. Chief, Tech. Planning Div., Aero. Chart & Information Center (St. Louis).

Beattie, Eugene M., Mgr., Flight Operations, General Electric Co. (White Plains).

Bossange, Edouard R., Jr., B.S., Engrg. Supt., Pan American World Airways (San Francisco).

Bower, Angus B., M.S. in Ae.E., Sr. Aerodynamics Engr., Convair Div. (San Diego), General Dynamics Corp.

Brickman, Eugene L., B. of M.E., Design Engr., Anderson, Greenwood & Co.

Brush, Don O., M.S. in Theoretical & Appl. Mech., Instructor in Theoretical and Appl. Mech., Univ. of Illinois.

Buchman, Walter H., Jr., Proj. Engr., Aircraft Armaments, Inc.

Buckley, Robert F., B.S. in M.E., Mgr., Aircraft Flowmeter Design Engrg., General Electric Co. (Lynn).

Butcher, J. S., Chief Designer, Field Aircraft Services, Ltd. (Nottingham).

Bynum, George T., B.S. in M.E., Chief Engr., Aero. Div., Minneapolis-Honeywell Regulator Co.

Cahill, James B., B.S. in M.E., Sr. Proj. Engr., Allison Div., General Motors Corp. (Indianapolis).

Carter, Robert L., B. of M.E., Mgr., CJ805 Program, AGT Div., General Electric Co. (Cincinnati).

Carver, Leon, B.S. in M.E., Sr. Proj. Engr., Sperry Gyroscope Co. Div., Sperry Rand Corp.

Cokeley, Edmond R., M.S. in Ae.E., Sect. Head, Engrg. Flight Test, North American Aviation, Inc. (Los Angeles).

Crawshaw, Robert L., Engrg. Test Pilot, Cessna Aircraft Co.

Cunningham, William E., B.S. in M.E., Engrg. Test Pilot, The Glenn L. Martin Co.

Foote, John D., Engrg. Aide, Chance Vought Aircraft, Inc.

Ford, Birchard H., B.S. in E.E., Dir.—Research, Summers Gyroscope Co.

Freeguard, Leslie A., Design Engr., Convair Div. (San Diego), General Dynamics Corp.

Gitlin, Robert M., M. of Admin. Engrg., Chief Mech. Proj. Engr., Servomechanisms, Inc.

Habel, Louis W., E.E., Tech. Engr., Aircraft-Nuclear Propulsion Dept., General Electric Co. (Evendale).

Henninger, Paul E., Sr., Chief Engr., Redco Tool Div., Red Lion Cabinet Co.

Herman, Kenneth, Major, USAF; Aero. Engrg. Student, Univ. of Illinois.

Heselton, Clifford H., Jr., B.S. in C.E., Design Engr., Lockheed Aircraft Corp. (Burbank).

Hohmann, Bernhard A., Aero. Research Engr., ARDC, WADC (Dayton).

Imster, Harry F., M.S. in Ae.E., Dept. Head, Thermodynamics, McDonnell Aircraft Corp.

Jacobs, Kenneth H., B.S. in M.E., Chief, Engrg. Div., Chicago Midway Laboratories.

Johnson, Virgil E., Jr., S.M., Aero. Research Scientist, NACA (Langley Field).

Kennedy, Thomas L., B. of Ae.E., Engr., ARO, Inc.

Klumpp, James H., Ph.D., Research Engr. "A," Missile Systems Div., Lockheed Aircraft Corp. (Van Nuys).

Koepsell, Paul L., M.S. in C.E., Stress Analyst, Boeing Airplane Co.

Martin, James F., B. of Ae.E., Equipment Branch Head, Wind Tunnel Dept., Cornell Aeronautical Lab., Inc.

Matlock, Ray, Mgr., Eastern Sales Office, Meletron Corp.

McDonough, Peter J., B.A., Sr. Staff Engr., Motorola, Inc.

Morrison, William D., Jr., B.S., Aerodynamicist, McDonnell Aircraft Corp.

Nupp, Ralph E., B.S. in Ae.E., Engrg. Test Pilot, Air Arm Div., Westinghouse Electric Corp. (Baltimore).

Olesten, Nils-Olof, B.S. in M.E., Mfg. Research Engr., Lockheed Aircraft Corp. (Marietta).

Olver, Colin V., Chief Devel. Engr., British Aviation Services (London).

Peek, Alma J., B.S. in M.E., Design Engr., Lockheed Aircraft Corp. (Marietta).

Perkins, Douglas S., B.S., Thermodynamicist "A," National Rocket Corp.

Roberts, William E., B.S. in M.E., Experimental Engr., Allison Div., General Motors Corp. (Indianapolis).

Russell, Maurice G., Proj. Designer Draftsman, Auster Aircraft, Ltd. (England).

Sadler, Clinton E., B.S. in Ae.E., Propulsion Systems Engr., McDonnell Aircraft Corp.

Samson, Charles H., Jr., Ph.D., Sr. Aerodynamics Engr., Convair Div. (Ft. Worth), General Dynamics Corp.

Scheutzow, Wilbur J., Asst. Staff Engr., Armament, Cleveland Ordnance Plant, Cadillac Motor Car Div., General Motors Corp.

Schwartz, Walter, B. of Ae.E., Member, Tech. Staff, The Ramo-Wooldridge Corp. (Hawthorne).

Skladal, Conrad, Jr., M.B.A., Group Engr., Missile Systems Div., Lockheed Aircraft Corp. (Van Nuys).

Stevens, Daniel T., B. of M.E., Prelim. Design Proj. Leader, North American Aviation, Inc. (Columbus).

Taylor, Norman C., B.S. in M.E., Chief Engr., Vertol Aircraft Corp.

Walton, Lewis J., B.S. in Ae.E., Experimental Test Pilot, Chance Vought Aircraft, Inc.

Ward, J. P., B.S. in Indus. Engrg., Lead Designer, Chance Vought Aircraft, Inc.

Wilcox, Ward W., B.S. in M.E., Aero. Research Scientist, NACA (Langley Field).

Williams, James L., B.S. in Ae.E., Aero. Research Engr., NACA (Langley Field).

Transferred to MEMBER Grade

Burton, Clarence A., B.S. in Ae.E., Design Engr. "B," Lockheed Aircraft Corp. (Burbank).

Clinton, Robert L., M.S. in Ae.E., Specialist, Application Planning, General Electric Co. (Evendale).

Cox, Carl B., M.S. in Ae.E., Research Specialist, Aerodynamics, Boeing Airplane Co.

Grieco, Joseph P., B. in Ae.E., Power Turbines Engr., AiResearch Manufacturing Co.

Hallowell, Frederick C., Jr., S.M. in Ae.E., Aero. Engr., Warfare Research Dept., U.S. Naval Air Development Center.

Kam, Clifford, Y. K., M.S., Designer "A," Douglas Aircraft Co., Inc. (Santa Monica).

Marty, John L., B.S. in Ae.E., Group Engr., Prelim. Design, Weights, North American Aviation, Inc. (Columbus).

Mracek, Milo F., B.S. in Ae.E., Lead Design Engr., Airframe Div., McDonnell Aircraft Corp.

Papadopoulos, James G., B.S. in Ae.E., Sr. Struct. Engr., Convair Div. (Ft. Worth), General Dynamics Corp.

Sierra, Celestino R., Jr., B.S. in Ae.E., Sr. Design Engr., Convair Div. (Ft. Worth), General Dynamics Corp.

Elected to Associate Grade

Barrett, Cooper A., Struct. Engr., Temco Aircraft Co.

Chasen, Lawrence I., Mgr., Library, Special Defense Projects Dept., General Electric Co. (Philadelphia).

Dane, Ken P., V-P, Autry, Rushin & Dane, Inc.

Habberley, Alan C., B.S., Capt., DC-6 and DC-7, United Air Lines (Denver).

Hallberg, Walter L., Supvr., Wind Tunnel Model, North American Aviation, Inc. (Downey).

Hess, Thomas E., B. of C.E., Engr., Thermal Stress and Creep, General Electric Co. (Philadelphia).

Ivey, Harold K., B.S., Field Rep., Aerojet-General Corp.

Knowlton, Donald A., B. of E.E., Sales Engr., General Electric Co. (Denver).

Miner, Lawrence N., B.A., Engr., The Glenn L. Martin Co.

Mukhar, George E., B.S. in Ae.E., Design Engr., Convair Div. (San Diego), General Dynamics Corp.

Noonan, Elmer J., B.S., Supvr., Engrg. Indus. Relations, Northrop Aircraft, Inc.

Paterson, William C., B.S. in M.E., Experimental Engr., Allison Div., General Motors Corp.

Remke, Richard W., Market Analyst, General Electric Co. (Evendale).

Richardson, David L., S.M., Research Engr., United Aircraft Corp. (East Hartford).

Sharp, Edward G., General Mgr., Jarvis Manufacturing Corp.

Tamosaitis, Anthony, M.S., Proj. Engr., Chicago Aerial Industries, Inc.

Taylor, William A., Design Engr., Duwes Engineering Co.

Van Hoven, Woodrow J., V-P, U.S. Aviation Underwriters, Inc.

Walden, Jesse J., Jr., Mgr., Convair Div. (San Antonio), General Dynamics Corp.

Transferred to Associate Grade

Ashburn, Madison, H., Jr., B.S. in Ae.E., Design Engr., Cessna Aircraft Co.

Beyer, Richard S., B.S. in M.E., Capt., USAF; Aero. Engr. (Wright-Patterson AFB).

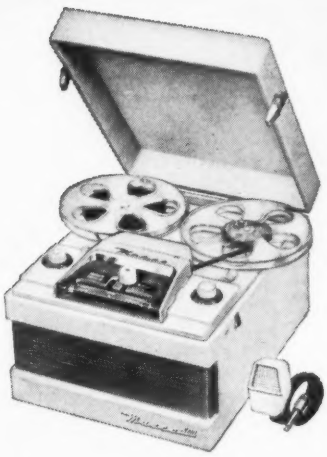
Boyer, Donald G., B.S. in Ae.E., Student, Tri-State College.

Chessman, Samuel R., B.S. in Ae.E., Student, USN, Orsort, Oak Ridge National Laboratory.

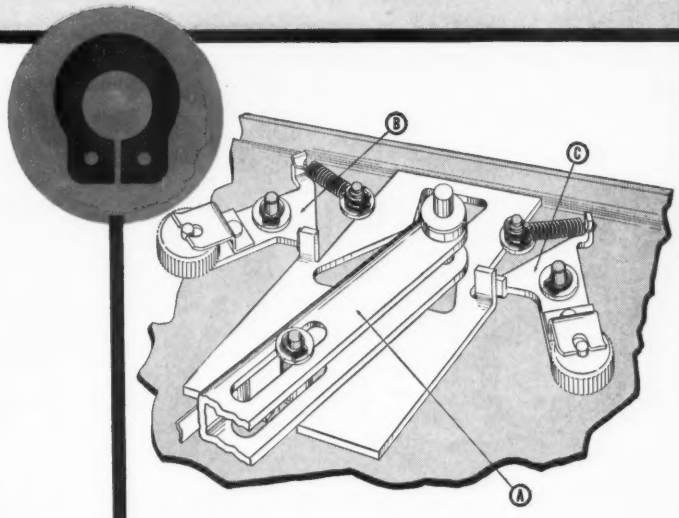
Cox, Sidney S., B.S. in Ae.E., Lt., USN; Student.

Curtis, William M., III, B.S. in M.E., Aerodynamics Engr., Convair Div. (Ft. Worth), General Dynamics Corp.

Waldes Truarc grip rings used on die-cast studs eliminate threading, tapping, other costly machining



Mark Simpson Manufacturing Co., Long Island City, N. Y., uses Waldes Truarc series 5555 Grip Rings to secure parts to studs of the zinc die-cast base of its "Masco 500" portable tape recorder.
The rings—which need no grooves—replace nuts, screws, cotter pins and other types of fastening devices which require threading, tapping, drilling and other expensive machining operations. Because a single cracked or broken stud would render the entire cast base useless—and with it, all assembly completed to that point—the rings also eliminate extremely costly rejects.



Pivot Assembly of shift lever (A) is secured by a single Waldes Truarc Grip Ring and washer. Because the washer must be installed over the shift level in a sliding fit, critical tolerances would have to be maintained if a screw or cotter pin were used. The Truarc Grip Ring eliminates that problem: it requires no groove and may be seated over the washer at any point on the stud, automatically compensating for accumulated tolerances in the parts. BRAKE ASSEMBLIES (B and C) use Grip Rings to secure the brake wheel and spring subassemblies. Here again problems of critical tolerances are avoided and expensive rejects eliminated.

Whatever you make, there's a Waldes Truarc Retaining Ring designed to improve your product... to save you material, machining and labor costs. They're quick and easy to assemble and disassemble, and they do a better job of holding parts together. Truarc rings are precision engineered and precision made, quality controlled from raw material to finished ring.

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Aeronautical Reviews

A Guide to the Current Literature of Aeronautical Research and Engineering

THIS SECTION reviews important periodicals, technical and research reports, and books received in the IAS Library in order to provide basic documentation for engineers and scientists.

INTERNATIONAL AERONAUTICAL ABSTRACTS, published as an insert in each issue, is an accelerated reviewing service covering worldwide scientific and technical literature. This work is performed by the IAS Staff and is supported by the Air Force Office of Scientific Research of the Air Research and Development Command.

A list of the periodicals and reports series received in the IAS Library is published semiannually, in the January and July issues.

The AERONAUTICAL ENGINEERING INDEX, published since 1947, provides an annual cumulation of the materials reviewed in this section.

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Acoustics, Sound, & Noise

Noise, Vibration, and People. Horace O. Parrack. (*IAS 24th Annual Meeting, New York, Jan. 23–26, 1956, Paper.*) *Noise Control*, Nov., 1956, pp. 10–24.

Tentative Method for Calculation of the Sound Field About a Source Over Ground Considering Diffraction and Scattering Into Shadow Zones. Appendix—**Two-Dimensional Analysis of Diffracted Field in Wind-Created Shadow; Cylindrical Source in Wind Gradient.** David C. Pridmore-Brown and Uno Ingard. *U.S., NACA TN 3779*, Sept., 1956. 33 pp.

The Oblique Reflexion of Sound Pulses. J. W. Craggs. *Proc. Royal Soc. (London), Ser. A*, Nov. 6, 1956, pp. 372–382.

Attenuation and Scattering of Ultrasonic Waves in a Medium with Spherical Inhomogeneities. I. Malecki. *Bul. Acad. Polonaise Sci.* (Warsaw,) No. 3, 1956, pp. 173–178. 10 refs. Investigation of a medium without initial stresses, in which there are spherical inclusions filled with another medium.

A Method for Calculation of Free-Space Sound Pressures Near a Propeller in Flight Including Considerations of the Chordwise Blade Loading. Charles E. Watkins and Barbara J. Durling. *U.S., NACA TN 3809*, Nov., 1956. 68 pp.

Messung und Beurteilung von Flugzeuggeräuschen auf Grund praktischer Erfahrungen. F. J. Meister. *Luftfahrttechnik*, Nov. 15, 1956, pp. 201–205. In German. Includes data on DC-6, Viscount, and Super Constellation as part of a program for the determination and measurement of aircraft noise in the vicinity of an airport.

Jet-Engine Noise Reduction Research at NACA. Newell D. Sanders and Edmund E. Callaghan. *Noise Control*, Nov., 1956, pp. 43–48.

Experiments on the G. S. Flame-Guard Depressor Silencer. Luigi Stipa. (*L'Ingegnere*, July-Aug., 1939, pp. 605–610, 706–710.) *Miss. State Coll., Aerophys. Dept.*, Aug. 7, 1956, Reprint. 42 pp. Translation. Investigation of a muffler composed of an elongated tube with a tapered external shape and of good aerodynamic penetration with the longitudinal axis placed in the direction of travel. The study was made to develop a muffler for silencing, for lowering the pressure of the exhaust, and for achieving obscurement of the flames of the exhaust gases.

Aerodynamics

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The Slotted-Blade Axial-Flow Blower H. E. Sheets. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *Trans. ASME*, Nov., 1956, pp. 1,683–1,690; Discussion, p. 1,690. 11 refs. Test data of an experimental blower indicating blower efficiencies to 94 per cent and stage efficiencies to 96 per cent with high-pressure coefficients corresponding to a maximum flow deflection of about 52°.

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Flight Experiments on the Boundary Layer Characteristics of a Swept Back Wing. L. D. Allen and F. M. Burrows. *Coll. of Aeronautics, Cranfield, Rep. 104.*

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July, 1956. 56 pp. 15 refs. Tests to study the transition mechanism from in-flight boundary-layer measurements on an untapered, untwisted 45° sweptback half wing of thin symmetrical section mounted vertically on top of the fuselage of an Anson Mark I aircraft.

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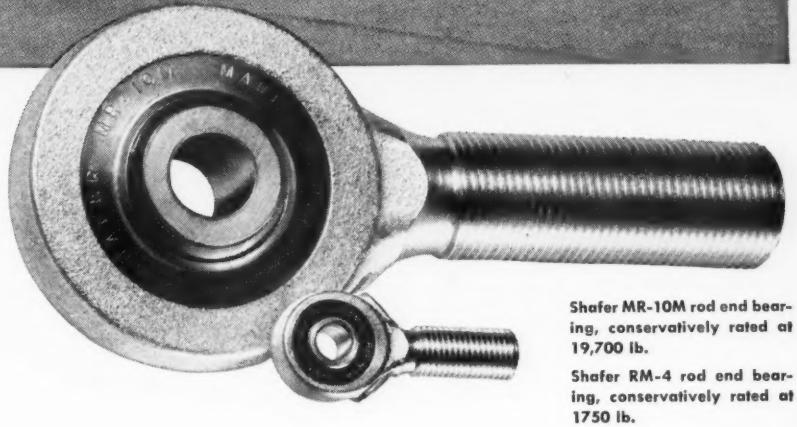

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Section Characteristics of the NACA 0006 Airfoil with Leading-Edge and Trailing-Edge Flaps. Bruno J. Gambucci. *U.S., NACA TN 3797*, Dec., 1956. 17 pp. Lift, pitching-moment, and pressure-distribution data for various leading- and trailing-edge flap deflections obtained from tests conducted in one of the Ames 7- × 10-ft. wind tunnels.

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The Displacement Effect of a Sphere in a Two-Dimensional Shear Flow. Appendix—**Shear Flow Past Two-Dimensional Bodies.** I. M. Hall. *J. Fluid Mech.*, July, 1956, pp. 142–162. 10 refs. Investigation of the displacement effect of a pitot tube in shear flow. Viscosity is neglected so that the vorticity field alone is considered. A solution is obtained in the plane of symmetry for spheres in shear flow.

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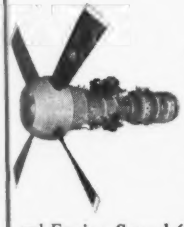

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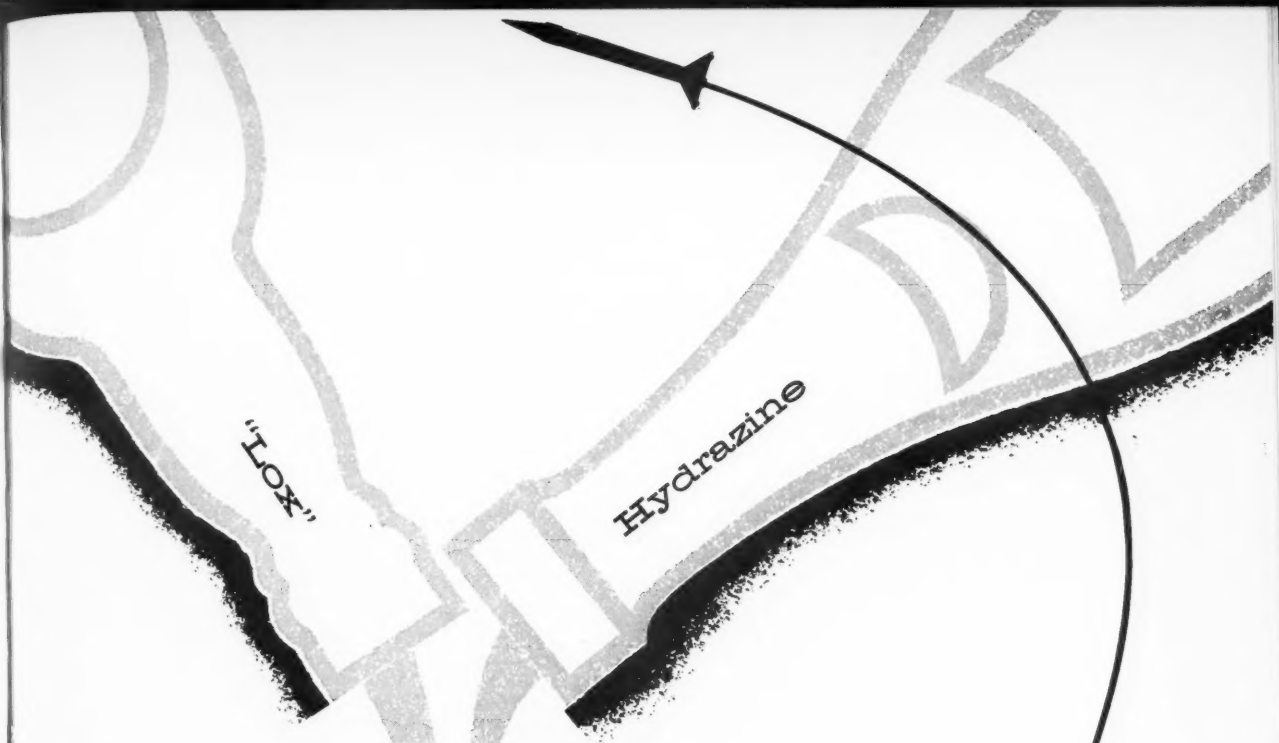

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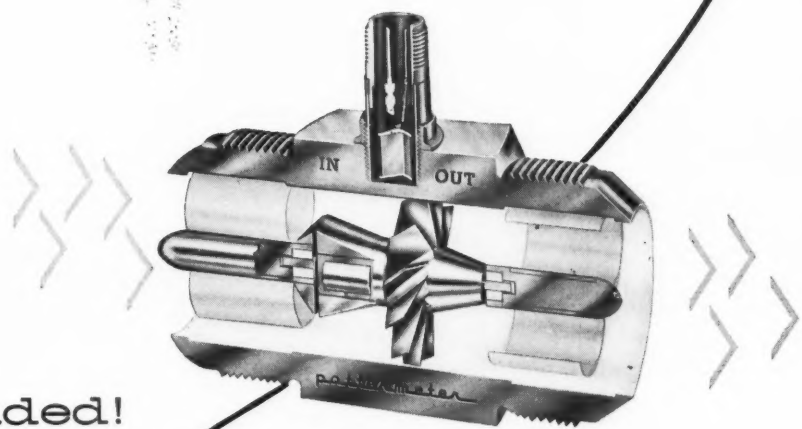

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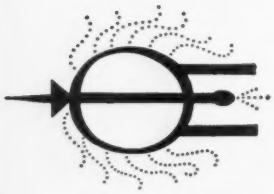

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Wind-Tunnel Investigation to Determine the Horizontal- and Vertical-Tail Contributions to the Static Lateral Stability Characteristics of a Complete-Model Swept-Wing Configuration at High Subsonic Speeds. James W. Wiggins, Richard E. Kuhn, and Paul G. Fournier. *U.S., NACA TN 3818*, Nov., 1956. 34 pp.

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On the Kernel Function of the Integral Equation Relating Lift and Downwash Distributions of Oscillating Wings in Supersonic Flow. Appendix A—**Derivation of Equation (16c) and Reduction of the Kernel Function to the Sonic Case.** Appendix B—**Derivation of Downwash Functions Associated with "Horseshoe" Vortices in Supersonic Flow.** Charles E. Watkins and Julian H. Berman. *U.S., NACA Rep. 1257*, 1956. 18 pp. 19 refs. Supt. of Doc., Wash., $0.20.

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Aerodynamic Characteristics and Flying Qualities of a Tailless Triangular-Wing Airplane Configuration as Obtained from Flights of Rocket-Propelled Models at Transonic and Low Supersonic Speeds. Appendix—**Reduction of Data and Methods of Analysis.** Grady L. Mitcham, Joseph E. Stevens, and Harry P. Norris. *U.S. NACA TN 3753*, Nov., 1956. 57 pp.

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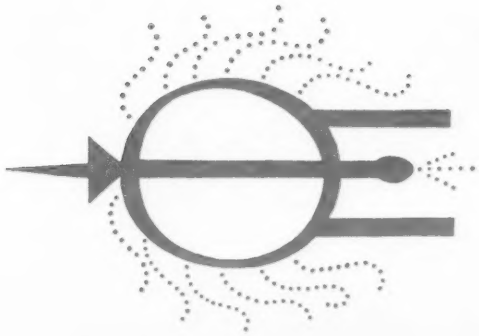
Corrected Discontinuities in Structural Stability Problems. A. H. Chilver. *J. Mech. & Phys. Solids*, Nov., 1956, pp. 9–17. Description of a method for deriving the basic differential equations of a structural-stability problem.



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Aerodynamic Theory and Its Application to Flutter. I. E. Garrick. (*NATO AGARD Structures & Materials Panel.*) *U.S., NACA Paper,* Apr., 1956. 38 pp. 33 refs. Survey of the present status of aerodynamic theory for both sub- and supersonic speed ranges in relation to flutter analysis, with discussion of concepts implied in the structural and aerodynamic background.

Flutter Calculations on a Rudder with Trailing-Edge Spoiler. Ll. T. Niblett. (*Gt. Brit., RAE Rep. Struc.202,* May, 1956.) *Gt. Brit., ARC CP 277,* 1956. 13 pp. BIS, New York, $0.45. Calculations of flutter on two different spoiler systems and comparison with flight-test data.

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Measurement of the Longitudinal Moment of Inertia of a Flexible Airplane. Appendix A—**Derivation of Airplane-Support Influence Coefficients.** Appendix B—**Apparent Inertia of a Mass-Spring System.** Henry A. Cole, Jr., and Frances L. Bennion. *U.S., NACA TN 3870,* Nov., 1956. 30 pp. Method of determining moment of inertia by oscillating an aircraft on knife edges and a spring. The analysis is applied to a flexible airplane mounted on various combinations of springs and knife edges.

Experimental Steady-State Yawing Derivatives of a 60° Delta-Wing Model as Affected by Changes in Vertical Position of the Wing and in Ratio of Fuselage Diameter to Wing Span. Byron M. Jaquet and Herman S. Fletcher. *U.S., NACA TN 3843,* Oct., 1956. 20 pp.

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Calculation and Compilation of the Unsteady-Lift Functions for a Rigid Wing Subjected to Sinusoidal Gusts and to Sinusoidal Sinking Oscillations. Appendix A, B—**Asymptotic Behavior of Oscillatory Lift Coefficients as Determined from Indicial Lift Functions.** Appendix C—**Indicial Lift Function for Delta Wing of Vanishing Aspect Ratio in Compressible Flow Penetrating a Sharp-Edged Gust.** Joseph A. Drischler. *U.S., NACA TN 3748,* Oct., 1956. 59 pp. 23 refs.

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Fatigue Loadings in Flight: Loads in the Wing of a Varsity. Anne Burns. (*Gt. Brit., RAE TN Struc.192,* May, 1956.) *Gt. Brit., ARC CP 285,* 1956. 23 pp. BIS, New York, $0.72.

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L'Enregistrement sur Bande Magnétique Adapté aux Essais en Vol. A. Bleys and P. Mathon. *La Recherche Aéronautique,* Sept.-Oct., 1956, pp. 51, 52. In French. Description of a device used for recording transient response of aircraft structures in flight.

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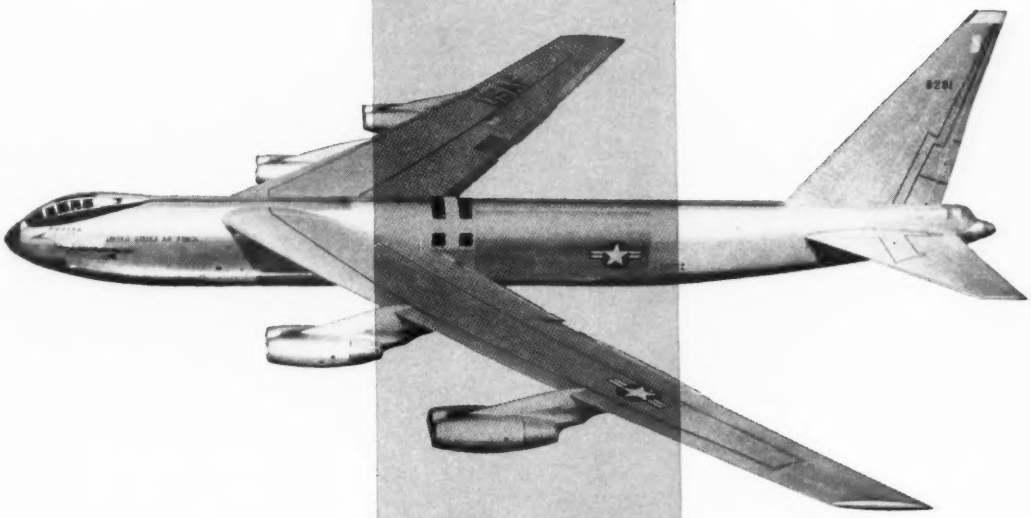

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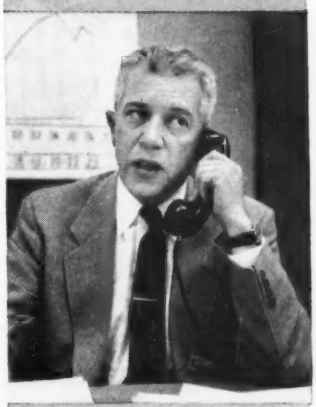

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Engineering Study of Air Conditioning Load Requirements for Aircraft Compartments. W. L. Torgeson, H. C. Johnson, and N. B. Wright, Jr. *USAF WADC TR 55-254 [AD 90530]*, June, 1955. 185 pp. 34 refs. Methods for calculating the cabin air-conditioning loads in modern aircraft. Treatments are given for both the steady-state and the transient cases.

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Performance Characteristics of Ring-Cascade-Type Thrust Reversers. Jack G. McArdle. *U.S., NACA TN 3838*, Nov., 1956. 53 pp. Experimental investigation, in quiescent air, of model ring-cascade reversers, each consisting of a cascade of turning rings plus a mechanical deflector positioned aft of a 4-in. exhaust nozzle with a 7° external fairing, to determine the effect of geometric design variables on performance and reversed-flow fields.

Seat Design for Crash Worthiness. I. Irving Pinkel and Edmund G. Rosenberg. *U.S., NACA TN 3777*, Oct., 1956. 42 pp. Study of several crash deceleration records from which a simplified model of a crash deceleration pulse is suggested.

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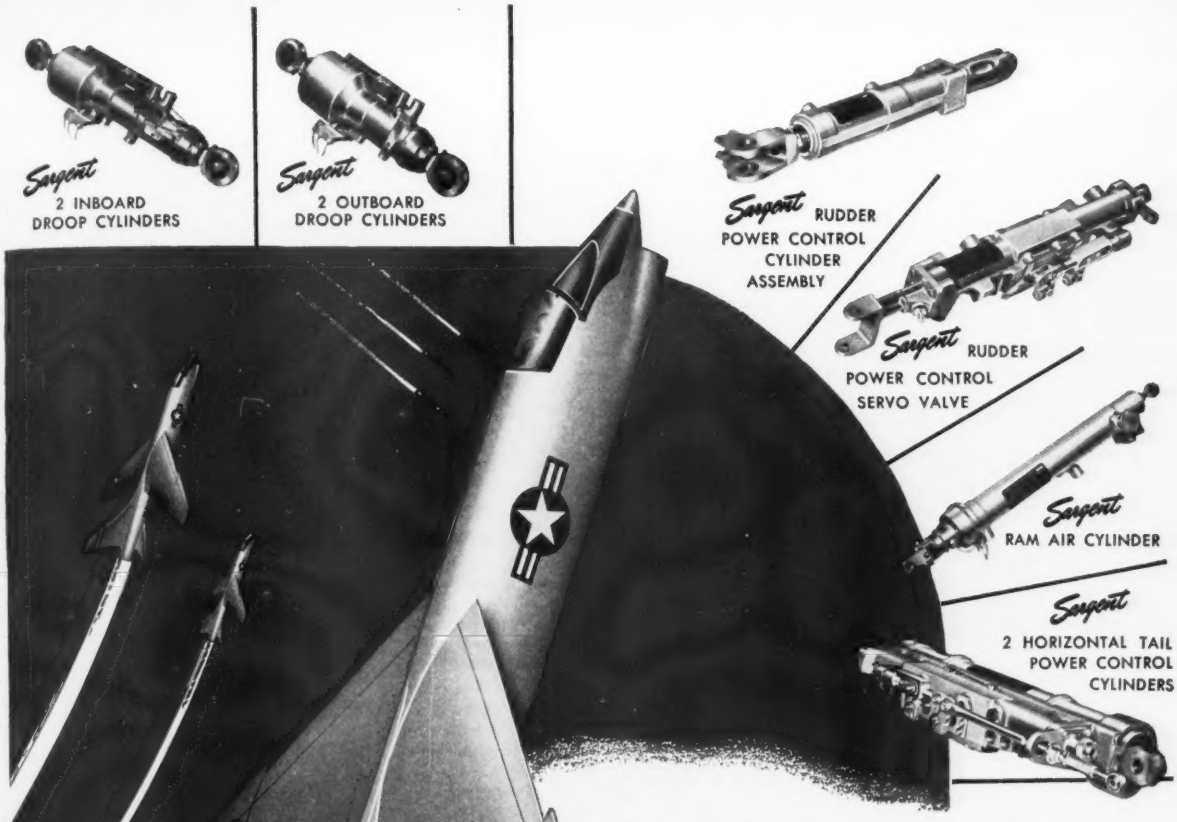

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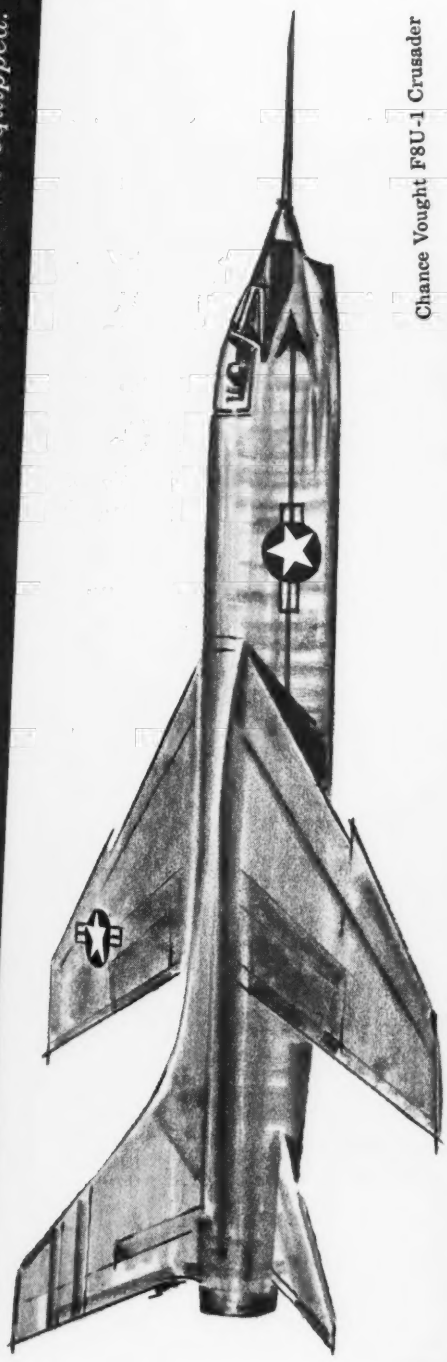

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The Structure and Low Temperature Embrittlement of Titanium-Aluminium

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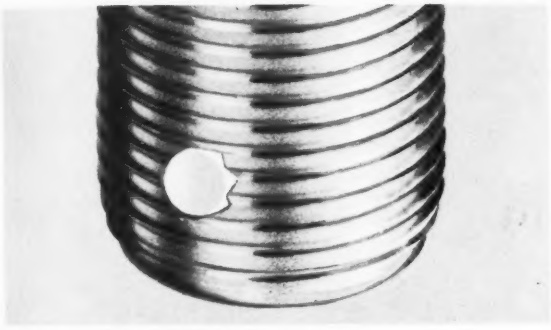
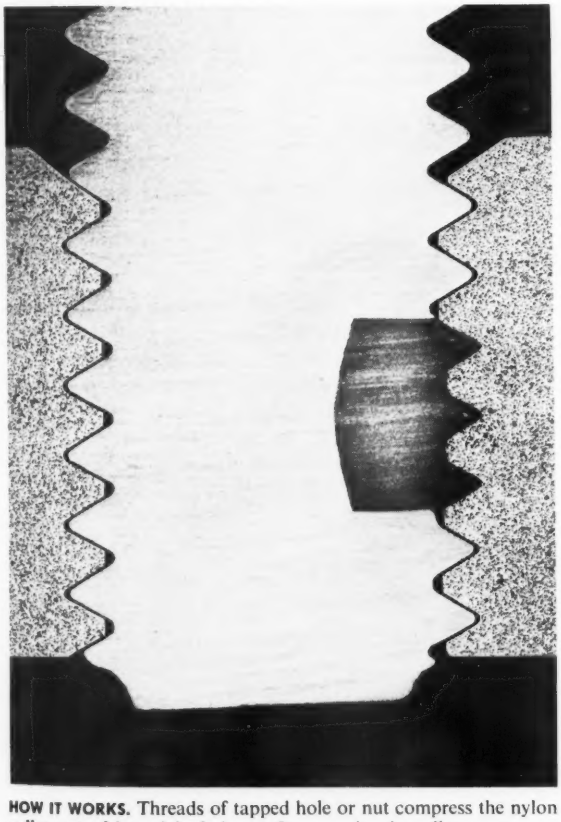
(*Continued on page 151*)

NEW—SPS aircraft bolts with the Nylok* self-locking device



THE NYLOK SELF-LOCKING DEVICE consists of a nylon pellet permanently installed in the threaded section of the bolt. It completely eliminates the need for all other locking devices, including expensive, time-consuming lockwiring. It is available in all standard and special SPS and Cooper fasteners with male threads.



HOW IT WORKS. Threads of tapped hole or nut compress the nylon pellet out of its original shape. Compression in pellet exerts continual force against mating threads—locks the bolt positively. Bolts are reusable.

Vibration cannot shake them loose. They simplify design and save production time.

SPS aircraft bolts are now available embodying the Nylok self-locking device, which provides a truly practical new solution to the problem of making bolts self-locking.

A self-locking SPS aircraft bolt is a single unit. No auxiliary locking devices are needed. Just thread the bolt into any tapped hole. *Seated or not*, it locks positively wherever wrenching stops. The tough, resilient nylon pellet forces mating threads together and holds tight. The screw will not shake loose.

You save production time when you assemble aircraft with self-locking SPS bolts. You get more simplicity in design, with less bulk and weight. The number of parts you must assemble to achieve full locking action is reduced to the absolute minimum. Expensive drilling and deburring of heads for lockwires is eliminated. So is the installation of lockwires—a costly, tedious, time-consuming process, especially where bolts must be installed in cramped, inaccessible places. And the nylon pellet locks the screw positively—while lockwires frequently permit the screw to back off slightly under vibration and lose its preload. These bolts save maintenance time, too—no lockwires to cut and untangle and reinstall.

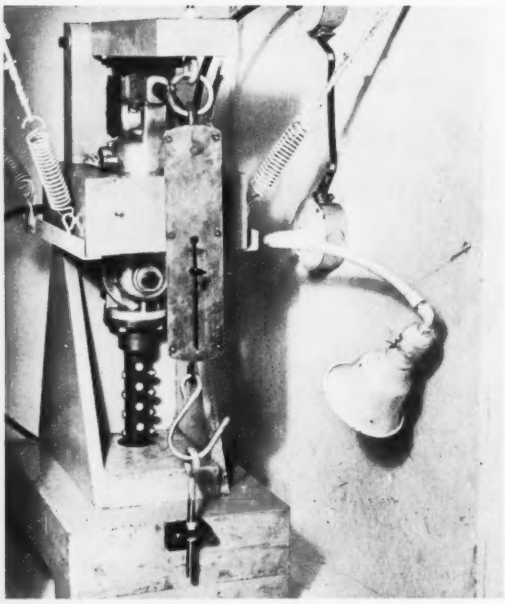
Self-locking SPS aircraft bolts are reusable. They have uniform locking torque and low installation torque—with no galling or seizing on mating threads. They successfully withstand temperatures from −70 to 250°F.

SPS manufactures male-threaded fasteners with the Nylok self-locking device in standard or special configurations—for use in conventional applications and in many places where bolts cannot be locked by any other means. The Nylok device is also available in fasteners manufactured by Cooper Precision Products, an SPS subsidiary.

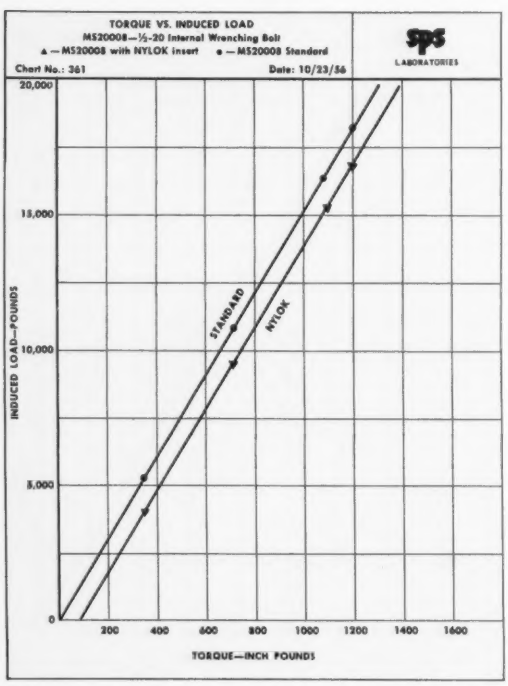
Write us for complete information on SPS self-locking threaded aircraft fasteners today. Aircraft Products Division, STANDARD PRESSED STEEL CO., Jenkintown 58, Pa.

*T.M. Reg. U.S. Pat. Off., The Nylok Corporation

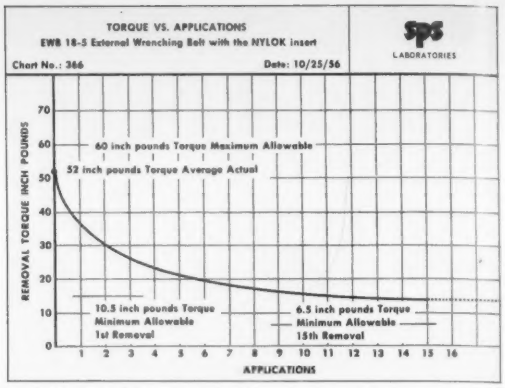
Lab tests prove self-locking SPS bolts are safe and strong



VIBRATION RESISTANCE. Exhaustive vibration resistance tests, conducted in the equipment shown above, proved that self-locking SPS fasteners, properly tightened, maintain their preload under exceptional conditions.



INDUCED LOAD. Curve shows difference in torque required to produce equal bolt loads with use of a standard aircraft fastener and a self-locking SPS fastener. The fastener with the Nylok device displaces the standard curve uniformly by an amount equal to the unloaded prevailing torque.

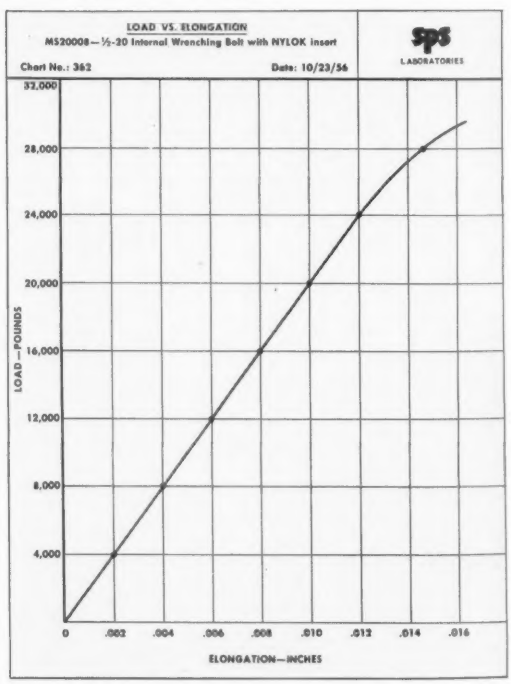


REMOVAL TORQUE. Curve shows removal torque in inch-pounds through the 15th application. Even after being inserted and removed from a tapped hole more than 15 times, the SPS fastener retains a value well above the minimum allowable torque of 6.5 in.-lb.

COMPARISON OF TENSILE STRENGTH
SELF-LOCKING MS BOLT VS. STANDARD MS BOLT

Sample No.	Tensile strength—pounds	
	MS 20008 with Nylok Insert	Standard MS 20008
1....	29,575	29,400
2....	29,250	29,575
3....	29,400	29,725
4....	29,850	29,600
5....	29,600	29,810

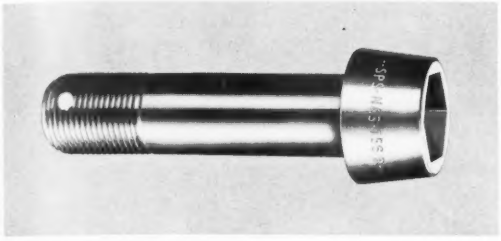
TENSILE VALUES. Tensile strength comparison shows that there is no significant difference in tensile strength between a standard SPS aircraft bolt and a comparable SPS bolt with the Nylok* device added.



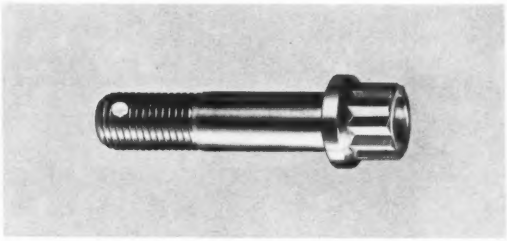
LOAD VS. ELONGATION. Test proves conclusively that the Nylok pellet has no effect on the strength of the fastener. It shows a continuous uninterrupted curve, with values identical to those for a comparable standard bolt.

*T.M. Reg. U.S. Pat. Off., The Nylok Corporation

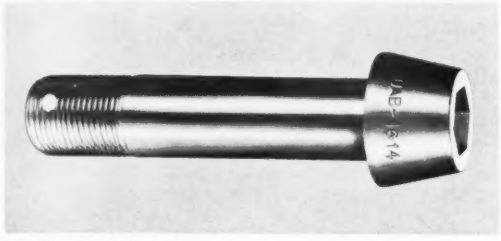
SPS aircraft fasteners with the Nylok* self-locking device



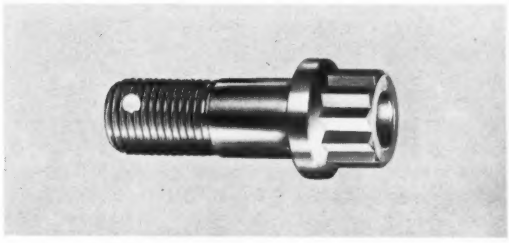
Internal wrenching bolt
NAS 144 through 176 type
Manufacturing Specification NAS 159



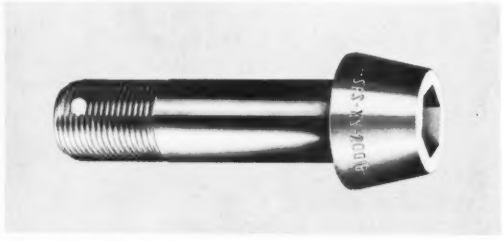
12-point external wrenching airframe bolts



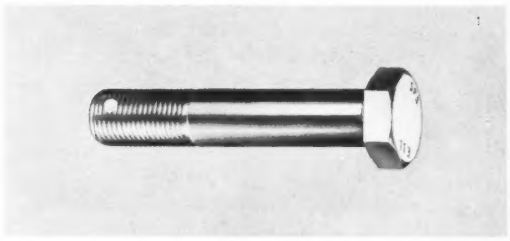
Internal wrenching bolt
UAB 428 through 2424 type
Manufacturing Specification NAS 159



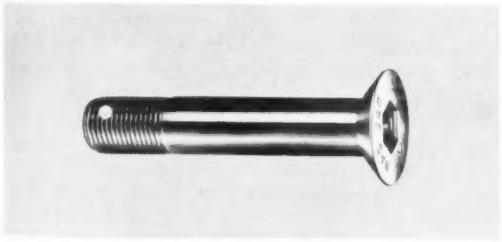
12-point external wrenching engine bolts
MS 9033-05 through 9039-52 type
Manufacturing Specification AMS 7478



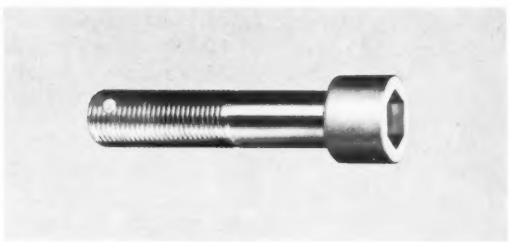
Internal wrenching bolt
MS 20004 through 20024 type
Manufacturing Specification MIL-B-7838a



6-digit external wrenching bolt
Manufacturing Specification AMS 7452 or 7472



100° flush head shear bolts
NAS 333 through 340 type
Manufacturing Specification NAS 498



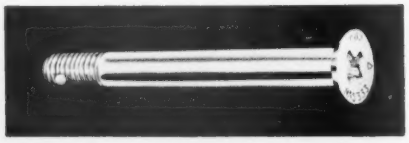
6-digit internal wrenching bolt
Manufacturing Specification AMS 7452 or 7472

Aircraft fasteners in many hundreds of special configurations are manufactured by SPS. All special fasteners with male threads can be equipped with the Nylok device.

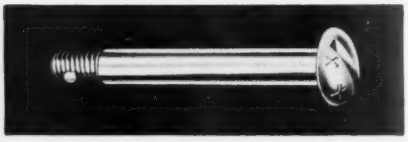
*T.M. Reg. U.S. Pat. Off., The Nylok Corporation

Cooper aircraft fasteners with the Nylok* self-locking device

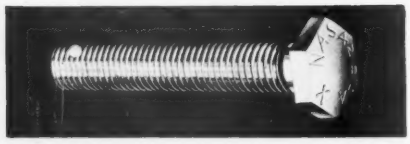
AN 3 through AN 20 type
Manufacturing Specification MIL-B-6812



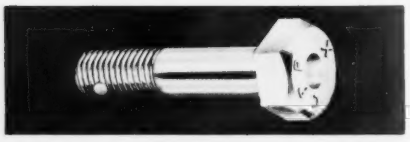
NAS 333 through NAS 340 type
Manufacturing Specification NAS 498



AN 21 through AN 36 type
Manufacturing Specification MIL-B-6812

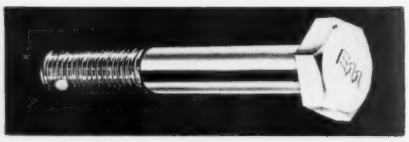


NAS 428 type
Manufacturing Specification MIL-B-6812

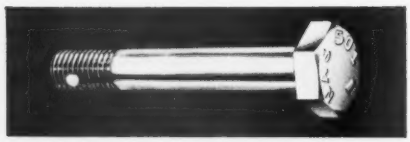


NAS 1303 through 1320 type
Manufacturing Specification MIL-B-7838

NAS 464 type
Manufacturing Specification NAS 498



AN 6-digit engine bolt type
Manufacturing Specifications AMS 7452 and 7472



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AERODYNAMICS

Aerothermodynamics

A NOTE ON THE EFFECT OF CENTRIFUGAL FORCES AND ACCELERATED MOTION ON THE INSTABILITY OF THE LAMINAR BOUNDARY LAYER ABOUT HIGHLY COOLED BODIES. Antonio Ferri and Roberto Vaglio-Laurin. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 313 (AFOSR TN 56-579) [AD 115002], Dec., 1956. 13 pp. Theoretical investigation of a possible transition mechanism on highly cooled surfaces having a large curvature, with particular emphasis on the destabilizing effect of centrifugal forces in steady flight and of the resultant inertia forces in unsteady flight in the presence of cooling. An intuitive description of the phenomenon is presented and checked qualitatively by energy considerations along the lines indicated for a similar problem by Prandtl. The effects of viscosity and of axial pressure are neglected.

THE SOLUTION OF COMPRESSIBLE LAMINAR BOUNDARY LAYER PROBLEMS BY A FINITE DIFFERENCE METHOD. I. Flügge-Lotz and D. C. Baxter. Stanford U., Div. Eng. Mech. TR 103 (AFOSR TN 56-544), Sept. 30, 1956. 77 pp. 32 refs. Method which allows the determination of boundary-layer behavior under any combination of pressure gradient and wall temperature, or heat-transfer rate variation. The stability of the finite difference solution of the boundary-layer equations, and of parabolic equations in general, has been investigated and found to place certain restrictions on the mesh sizes that may be used. The solution has been programmed for an IBM 650 digital computer, and the computation of an extensive series of examples under various combinations of heat-transfer rate and pressure have been started.

ON THE CALCULATION OF HEAT AND MASS TRANSFER IN LAMINAR AND TURBULENT BOUNDARY LAYERS. I - THE LAMINAR CASE. II - THE TURBULENT CASE. D. R. Davies and D. E. Bourne. Quart. J. Mech. & Appl. Math., Dec., 1956, pp. 457-488. 22 refs. Description of a method for calculating the rate of heat transfer from a plane wall into a laminar incompressible boundary layer, and of the method's application to obtain a solution for the problem of forced convection from a flat plate through a fully turbulent boundary layer when the surface of the plate is kept at a steady constant temperature.

OBLIQUE-SHOCK RELATIONS AT HYPERSONIC SPEEDS FOR AIR IN CHEMICAL EQUILIBRIUM. W. E. Moeckel. US, NACA TN 3895, Jan., 1957. 18 pp. Calculation of oblique-shock relations for flight velocities up to 25,000 ft. per sec. at altitudes up to 200,000 ft. Results show that those shock parameters which are functions only of Mach Number normal to the shock for an ideal gas are strongly influenced by flight altitude as well as normal Mach Number when dissociation takes place. The variation of flow-deflection angle with shock angle differs significantly from that of an ideal gas.

INVERSION OF THE PRANDTL-MEYER RELATION FOR SPECIFIC HEAT RATIOS OF 5/3 AND 5/4. R. F. Probstein. Brown U. Div. Eng., USAF WADC TN 56-497 [AD 110580], Nov., 1956. 12 pp. Analysis using an inversion of the usual form of the Prandtl-Meyer relation for an isentropic supersonic flow with constant specific-heat ratio. The inverted form allows the local Mach Number, and thus the pressure, to be expressed explicitly as a function of the turning angle. Both values of the specific heat ratios treated are shown to be of practical interest in connection with hypersonic and high-temperature gas flows.

ONE-DIMENSIONAL UNSTEADY FLOW OF MAGNETO-GASDYNAMICS. S. I. Pai. U. Md., Inst. Fluid Dynamics & Appl. Math. TN BN-86 (AFOSR TN 56-537) [AD 110356], Nov., 1956. 14 pp. Analysis of unsteady flow of a viscous, heat conducting, electrically conducting, and compressible

gas under planar magnetic field perpendicular to the velocity vector. The special case of an ideal gas which is inviscid, non-heat conducting, and infinite electrically is considered. An exact solution is obtained and shows the shock-wave formation in magneto-gasdynamics. Next the characteristics of these one-dimensional magneto-gasdynamics flow equations are examined. It is found that for a viscous fluid, the characteristics are the same as those of the corresponding problems in ordinary gas dynamics.

PAPERS ON HEAT TRANSFER AND UNSTEADY AERODYNAMICS. I - INTEGRAL METHODS FOR LAMINAR FORCED CONVECTION CALCULATIONS - AN EVALUATION OF TWO APPROACHES, J. A. F. Hill. II - A FURTHER NOTE ON AERODYNAMIC HEATING, Morton Finston. III - THE BINARY MIXTURE BOUNDARY LAYER ASSOCIATED WITH MASS TRANSFER, J. R. Baron. IV - EXPERIMENTS IN UNSTEADY AERODYNAMICS LEADING TO THE DEVELOPMENT OF AN ACOUSTIC DRAG COEFFICIENT, E. S. Rubin and E. M. Kerwin, Jr. (Appl. Mech., 9th Internatl. Cong., Brussels, Sept. 5-13, 1956.) MIT NSL TR 179, 1956. 59 pp. 30 refs. I - Consideration of the problem of calculating the distribution of heat-transfer rates over the forward part (i.e., up to the velocity maximum) of an isothermal body immersed in a uniform airstream whose velocity is low enough for the boundary layer to be laminar and for the effects of compressibility to be negligible. II - Derivation, for a simple case, of an exact solution to the complete problem of calculating simultaneously the temperature in a body and in the adjacent fluid which is in relative motion with respect to it. III - Consideration of the appropriate boundary-layer equations and their boundary conditions. Includes numerical results for some specific mixtures. IV - Discussion of the implications of the correspondence of acoustical measurements with concurrently obtained drag measurements, observed as a result of a series of tests to determine the influence of spikes attached to a blunt body in supersonic flow on the aerodynamic and thermodynamic characteristics of such models. An explanation of the phenomena is given which is based on a simplified physical model.

Boundary Layer

BOUNDARY LAYER MEASUREMENTS ON 10° AND 20° CONES AT M=2.45 AND ZERO HEAT TRANSFER. F. V. Davies and J. R. Cooke. Gt. Brit., ARC CP 264, 1956. 63 pp. 14 refs. BIS, New York, $1.53. Test results which show that transition from laminar to turbulent flow occur between four and six inches from the tip of a 10° cone at a Reynolds Number between 10^6 and 1.4×10^6; the layer on the 20° cone is laminar over its length of six inches up to a Reynolds Number of 1.4×10^6. Most of the data for laminar boundary layers are obtained from the 20° cone, and all the data for turbulent boundary layers from the 10° cone. Comparison is made with theoretical relations derived from flat-plate solutions, and gives reasonable agreement with such relations.

LAMINAR BOUNDARY LAYER ON A SPINNING CIRCULAR CONE IN SUPERSONIC FLOW AT A SMALL ANGLE OF ATTACK. Martin Fiebig. Cornell U. Grad. Sch. Aero. Eng. Rep. (AFOSR TN 56-532) [AD 110351], June, 1956. 61 pp. 14 refs. Development of the compressible laminar-boundary equations for bodies of revolution; application of these equations to the case of a rotating cone in supersonic flow at angle of attack; and derivation of a perturbation solution which is based on an available approximate solution of the outer nonviscous flow and introduces the Blasius similarity variable. The resulting system of differential equations is identified for first-order perturbations in angle of attack with Moore's equations, and for first- and second-order perturbations due to spin with Illingworth's equations. The differential equations due to interaction of angle of attack and spin are solved and the results are given in the form of a set of profile functions which yield, upon linear combinations, the solution for all Mach Numbers and cone-vertex angles.

BOUNDARY LAYER SEPARATION IN TWO-DIMENSIONAL SUPERSONIC FLOW. G. E. Gadd and D. W. Holder. Gt. Brit., ARC CP 270, 1956. 8 pp. 22 refs. BIS, New York, $0.45. Discussion of boundary-layer separation in supersonic flow which shows fairly sharp increase in pressure before separation. It is found that the ratio of the pressure at the separation point (S) to the pressure at the point (O) just upstream of the sharp pressure rise usually depends primarily on the external-flow Mach Number and state of the boundary layer at O, and is not greatly affected by the nature of the particular agency provoking separation.

LAMINAR BOUNDARY LAYERS ON MOVING WALLS. S. H. Smith. Cornell U. Grad. Sch. Aero. Eng. Rep. (AFOSR TN 56-454) [AD 96800]. Sept., 1956. 47 pp. Theoretical investigation into the nature of the boundary layer on a wall moving with a constant velocity. A solution of von Kármán's momentum equation is derived by applying Pohlhausen's method, in which a polynomial of the fourth degree - in terms of the distance from the wall - is assumed for the boundary-layer velocity distribution. In order to determine the flow pattern by means of the stream function, consideration is given to cases in which the potential flow is a linearly decreasing function of the distance along the wall. The streamlines are calculated by using Rott's exact solution to the Navier-Stokes equations for flow in the vicinity of a stagnation point, for the case of moving walls.

THE EFFECTS OF CONVEX SURFACE CURVATURE ON BOUNDARY LAYER SEPARATION IN SUPERSONIC FLOW. Appendix - THEORETICAL ANALYSIS OF THE DIRECT EFFECT OF SURFACE CURVATURE ON LAMINAR SEPARATION. G. E. Gadd. Gt. Brit., ARC CP 289, 1956. 16 pp. BIS, New York, $0.45. Theoretical and experimental investigation. The radius of curvature used in the tests is about three times the distance from the leading edge of the surface on which the boundary layer is formed to the separation point. Analytical results and test data agree that surface curvature

greatly reduces the separation pressure coefficient for laminar layers, but experiment indicates little effect for turbulent layers.

L'ASPIRATION DE LA COUCHE LIMITE EN TECHNIQUE AÉRONAUTIQUE. H. Schlichting. Tech. et Sci. Aéronautiques, No. 4, 1956, pp. 149-161. 26 refs. In French. Application of boundary-layer suction to develop methods for improving aerodynamic airfoil characteristics. Results show that the boundary layer can be kept laminar for high Reynolds Numbers, reducing drag considerably; and that separation can be avoided for large incidence, producing a considerable rise of the maximum lift coefficient.

INVESTIGATION OF THE EFFECTIVENESS OF BOUNDARY-LAYER CONTROL BY BLOWING OVER A COMBINATION OF SLIDING AND PLAIN FLAPS IN DEFLECTING A PROPELLER SLIPSTREAM DOWNWARD FOR VERTICAL TAKE-OFF. K. P. Spreemann and R. E. Kuhn. US, NACA TN 3904, Dec., 1956. 44 pp. Tests in a static-thrust facility at the Langley Aero. Lab. Investigation takes into account the effects of a leading-edge slat, ground proximity, end plate, and propeller position. Results indicate that boundary-layer control is an effective means of maintaining attached flow to flap deflections higher than those which could otherwise be used to provide increases in resultant force and turning angles, and that the only gains in these parameters with flap deflections at which the flow is not separated and at blowing rates above those necessary to maintain attached flow are those due to the direct thrust of the blowing system.

AVERAGE PROPERTIES OF COMPRESSIBLE LAMINAR BOUNDARY LAYER ON FLAT PLATE WITH UNSTEADY FLIGHT VELOCITY. Appendix A, B - DETERMINATION OF INTEGRALS FOR HARMONIC OSCILLATIONS. F. K. Moore and Simon Ostrach. US, NACA TN 3886, Dec., 1956. 35 pp. Theoretical investigation to determine the time-average characteristics in nearly quasi-steady flow for boundary layers over either insulated or isothermal plates. The only restrictions on plate velocity in the general investigation are that it should be positive and have an average value. Each time average involves two groups of terms - quasi-steady terms and terms related to the reduced frequency of the plate velocity functions. Results indicate that the former terms differ from the values for steady flow at the corresponding average velocity, these differences being reinforced by the frequency-dependent averages for adiabatic wall temperature and heat-transfer rate; that the effects oppose one another in the case of skin friction; that large amplitudes accentuate the importance of the frequency-dependent terms in the special case; and that, when the power to oscillate the plate is taken into account, oscillating the wall to increase the heat-transfer rate is advantageous only within a certain Prandtl Number range.

QUELQUES ASPECTS PHYSIQUES DU SOUFFLAGE SUR LES AILES D'AVION. Ph. Poisson-Quinton. Tech. et Sci. Aéronautiques, No. 4, 1956, pp. 163-195. 33 refs. In French. Extensive review of the literature pertaining to the mechanism of blowing for boundary-layer control. The analysis covers: the mechanism of blowing in incompressible flow, with fundamental parameters used; reduction of the minimum profile drag by blowing; lateral control of an airplane and aeroelastic damping; circulation control and the jet flap principle; boundary-layer control by blowing and combined suction and blowing; and separation control. Illustrated are: principle of circulation control and research development in combined suction and blowing, covering wind-tunnel and flight experiments.

FLOW AROUND ORIFICE UTILIZED FOR INJECTION OR SUCTION OF FLUID. Tetsushi Okamoto and Fusao Mikami. Tokyo Inst. Tech., Bul., Ser. B, No. 1, 1956, pp. 17-24. Analysis of the problems of sweat cooling and boundary-layer control, treating the flow around an orifice as the flow around a rectangular groove which has sources or sinks on its bottom surfaces. The analysis is restricted to the two-dimensional, incompressible potential flow. The stream lines and pressure distributions are shown for several cases.

Control Surfaces

WIND-TUNNEL INVESTIGATION OF AN EXTERNAL-FLOW JET-AUGMENTED SLOTTED FLAP SUITABLE FOR APPLICATION TO AIRPLANES WITH POD-MOUNTED JET ENGINES. J. P. Campbell and J. L. Johnson, Jr. US, NACA TN 3898, Dec., 1956. 47 pp. Experiments including tests of an unswept wing and of a swept-wing jet transport or bomber model, and using compressed-air jets exhausting from nozzles attached to the lower surface of the wings to simulate the jets from pod-mounted jet engines. Results indicate that external-flow jet-augmented flaps applied to existing aircraft of the type tested can produce lift coefficients sufficient to effect substantial reductions in take-off and landing speeds and distances.

WIND-TUNNEL INVESTIGATION OF JET-AUGMENTED FLAPS ON A RECTANGULAR WING TO HIGH MOMENTUM COEFFICIENTS. V. E. Lockwood, T. R. Turner, and J. M. Riebe. US, NACA TN 3865, Dec., 1956. 51 pp. Test results for a jet of air blown backward through a small gap, tangentially to the upper surface of a round trailing edge, and separated from the trailing edge at various angles up to 110° with respect to the wing chord line. In addition a limited number of tests were made of a jet-augmented plain flap and a jet-augmented trim flap. The results show that the ratio of total lift to jet-reaction lift increased with the increase in the jet deflection angle and reached a maximum value for jet deflection of 86° and 110°.

THE LIFT COEFFICIENT OF A THIN, JET-FLAPPED WING. D. A. Spence. Proc. Royal Soc. (London), Ser. A, Dec. 4, 1956, pp. 46-68. 15 refs. Derivation of a solution for the inviscid, incompressible flow past a thin, two-dimensional wing at a small incidence, at the trailing edge of which a thin jet emerges at a small deflection,

under the assumption that the flow inside the jet is irrotational and bounded by vortex sheets across which it is prevented from mixing with the main stream. The solution of an integral equation, obtained for the slope of the jet by aligning the trailing vortex sheet in the undisturbed-stream direction, is expressed as the sum of a Fourier series, together with a function possessing the correct (i.e., logarithmic) form of singular behavior at the trailing edge. Analysis includes calculation of the coefficients of a 9-term interpolation to the series on an electronic computer, and derivation of simple expressions for lift, pressure distribution, and pitching moment.

WIND-TUNNEL INVESTIGATION AT LOW SPEEDS TO DETERMINE THE EFFECT OF ASPECT RATIO AND END PLATES ON A RECTANGULAR WING WITH JET FLAPS DEFLECTED 85°. J. G. Lowry and R. D. Vogler. US, NACA TN 3863, Dec., 1956. 21 pp. Tests conducted with momentum coefficients as high as 17.5. Results indicate that the lift coefficient induced by the jet sheet (lift coefficient minus jet reaction in the lift direction) increases rapidly with increased aspect ratio, that various end plates increase the aspect ratio, and that the combination of the jet reaction at the trailing edge and the induced lift acting at the 0.4-chord station causes very large nose-down pitching-moment coefficients about the quarter chord of the wing.

Fluid Mechanics & Aerodynamic Theory

THE SIMILARITY RULES FOR SECOND-ORDER SUBSONIC AND SUPERSONIC FLOW. M. D. Van Dyke. US, NACA TN 3875, Jan., 1957. 20 pp. 11 refs. Extension of Göthert's similarity rule - and its supersonic counterpart - for linearized compressible flow theory. Analytical results indicate that any second-order subsonic flow can be related to "nearly incompressible" flow past the same body, which can be calculated by the Janzen-Rayleigh method.

AERODYNAMIC CHARACTERISTICS OF A CIRCULAR CYLINDER AT MACH NUMBER 6.86 AND ANGLES OF ATTACK UP TO 90°. J. A. Penland. US, NACA TN 3861, Jan., 1957. 32 pp. 12 refs. Pressure-distribution and force tests in the Langley 11-in. hypersonic tunnel. Results are compared with the Grimminger-Williams-Young hypersonic approximation, with a simple modification of the Newtonian flow theory, and data obtained at a lower Mach Number. It is shown that, while either of the analytical approaches gives adequate general aerodynamic characteristics, the modified Newtonian theory predicts pressure distribution more accurately. Results further indicate that the drag coefficient of a cylinder normal to the flow is relatively constant for Mach Numbers above about 4. The crossflow drag coefficients are calculated and plotted as a function of crossflow Mach Number.

TRANSONIC FLOW PAST THE TWO-DIMENSIONAL WEDGE WITH DETACHED SHOCK WAVE. II. Akira Takano. J. Japan Soc. Aero. Eng., Nov., 1956, pp. 8-14. Analysis of the boundary-value problem for the small perturbed function due to angle of attack, taken from the basic solution at zero angle of attack presented previously. Irrotational and inviscid flow is assumed in the whole region, and the small region of separation at the leading edge is ignored. The transformation formulas to the physical plane from the hodograph plane are treated by the present perturbation theory from the nonlifting case, and finally the local lift-curve shape is obtained as an example, and compared with the results of Vincenti and Wagoner.

A PROPOSAL CONCERNING LAMINAR WAKES BEHIND BLUFF BODIES AT LARGE REYNOLDS NUMBER. G. K. Batchelor. J. Fluid Mech., Oct., 1956, pp. 388-398. Study of a model of steady flow about a bluff body at large Reynolds Number which is different from the Helmholtz and Kirchhoff classical free-streamline model. It is suggested that although the free-streamline model may be a proper solution of the Navier-Stokes equation when $\mu \neq 0$, it is unlikely to be the limit as $\mu \to 0$ of the solution describing the steady flow due to the presence of a bluff body in an otherwise uniform stream. A closed wake contains a standing eddy whose general feature can be inferred from previous investigations of steady flow in a closed region. In all cases the drag coefficient on the body tends to zero as the Reynolds Number tends to infinity. The procedure for finding the details of a closed wake behind two-dimensional and axisymmetrical bodies is described.

SUPERSONIC ROTATIONAL FLOW AROUND A SHARP CORNER ON A BODY OF REVOLUTION. Hung-Ta Ho and Maurice Holt. Brown U. Div. Eng., USAF WADC TN 56-394 [AD 97273], Sept., 1956. 22 pp. Theoretical investigation of the singularity arising at the shoulder in the case of uniform hypersonic flow past a cone cylinder with detached bow wave. Analysis is carried out by means of series expansions in powers of the distance from the shoulder with coefficients depending on the angular coordinate based on the shoulder. The relevant singularity is the phenomenon of the fluid velocity becoming sonic, in the case considered, after increasing from the stagnation value along the cone face, and the flow expanding through a centered wave to become completely supersonic along the cylindrical afterbody. Analysis follows the Johannesen-Meyer treatment of expanding supersonic nozzles.

SUPERSONIC FLOW PAST A BLUFF BODY WITH A DETACHED SHOCK. I - TWO-DIMENSIONAL BODY. W. Chester. J. Fluid Mech., Oct., 1956, pp. 353-365. Analysis of flow at high Mach Number past a body with a rounded nose, neglecting viscosity and heat conduction. The body is assumed to be two-dimensional and symmetrical about an axis parallel to the incident stream. An exact solution is first obtained for the case of $\gamma \to 1$, $M \to \infty$, where γ is the adiabatic index and M is the Mach Number. This exact solution is then used as the basis of a double expansion after the exact solution has been modified to make the series expansion converge near the body. The results are given for values of $\delta^2(\gamma-1)(\gamma+1)$ and M^{-2}.

SUPERSONIC FLOW PAST A BLUFF BODY WITH A DETACHED SHOCK. II - AXISYMMETRICAL BODY. W. Chester. J. Fluid Mech., Nov., 1956, pp. 490-496. Theoretical investigation to derive expressions for the distance between the body and the shock, the radius of curvature of the shock compared with that of the body, and the pressure distribution on the body. Consideration is given to the flow at high Mach Number behind the curved shock formed when a supersonic stream impinges on an axisymmetrical body with a rounded nose. The solution is obtained as a double expansion in $\delta = (\gamma-1)/(\gamma+1)$, where γ is the adiabatic index, and M^{-2}; the expansion is developed to within terms of the order $(\delta + M^{-2})^3$.

ON THE THEORY OF HYPERSONIC FLOW PAST PLANE AND AXIALLY SYMMETRIC BLUFF BODIES. N. C. Freeman. J. Fluid Mech., Oct., 1956, pp. 366-387. 10 refs. Derivation of a solution for hypersonic flow, using boundary-layer techniques together with the von Mises variable x and ψ. The ratio of the specific heats is constant and equal to unity. A method of successive approximations is used when $\epsilon = (\gamma-1)(\gamma+1)$ and the free-stream Mach Number is infinite. Formulas for the streamlines, shock shape, and pressure distribution are derived. Particular results are computed for a number of special shapes. For certain shapes the theory has a singular point where the first approximation to the pressure vanishes ($\theta = 60^{\circ}$ for a sphere). When the pressure becomes too small, the theory is not applicable. The corresponding theory for gases of general thermodynamic properties is deduced. The method of approximation is valid provided the total energy of the gas is large compared with the energy contained in the translational modes of the gas molecules.

EXPERIMENTS ON CONE DRAG IN A RAREFIED AIR FLOW. D. C. Ipsen. Jet Propulsion, Dec., 1956, pp. 1,076, 1,077. Investigation of a cone of 15° half-angle conducted over a range of Reynolds Numbers from 70 to 1,500 at M=2, and 500 to 7,000 at M=4. The experimental drag curves are in fair agreement with available boundary-layer predictions if certain induced-pressure and transverse-curvature effects are included, although some difference in trend of the experimental and theoretical curves is evident.

ON THE DRAG OF SLENDER BODIES AT SONIC SPEED. S. B. Berndt. Sweden, Flygtekniska Försöksanstalten, FFA Medd. 70, 1956. 17 pp. Investigation of how the difference in nonviscous drag depends upon the difference in cross-sectional shape of equivalent bodies. The integral formula used expresses the drag acting in front of an infinite plane perpendicular to the free stream by means of the flow of momentum through that plane. In order to establish the applicability of this formula in combination with the concept of equivalence at sonic speed, some aspects of the limit procedure of letting the free-stream Mach Number approach one are discussed. The conclusion drawn is that, within the limitations of the approximate theory, the drag of a body having its cross-sectional area different from zero at the rear end may be considerably reduced by spreading out the area in a spanwise direction, leaving the distribution of cross-sectional area invariant.

MINIMUM-DRAG DUCTED AND CLOSED THREE-POINT BODY OF REVOLUTION BASED ON LINEARIZED SUPERSONIC THEORY. H. M. Parker. US, NACA TN 3704, Dec., 1956. 20 pp. Derivation of a solution without resort to slender-body approximations. Analysis includes complete calculations for the special case of a closed body with a given section (the third point) at the midbody position. It is shown that numerical procedures are required to evaluate the source-distribution function as well as the body shape. The existence of a corner at the third point is found to be characteristic of a linear solution to the minimum-drag three-point problem. It is concluded that the influence between the forward and rearward portions of a closed body results in a small increase in the radii of the minimum-drag shape.

THE METHOD OF CHARACTERISTICS FOR STEADY SUPERSONIC ROTATIONAL FLOW IN THREE DIMENSIONS. Maurice Holt. J. Fluid Mech., Oct., 1956, pp. 409-423. Extension of the Coburn and Dolph method to examine flow with shocks and entropy changes. Equations of motion are derived, and a scheme is described for solving these by finite differences. A linearized method of characteristics is developed for calculating the perturbations of a given three-dimensional field of flow. This is a generalization of the methods evolved by Ferri for perturbations of plane flow and conical flow.

METHOD FOR CALCULATING EFFECTS OF DISSOCIATION ON FLOW VARIABLES IN THE RELAXATION ZONE BEHIND NORMAL SHOCK WAVES. J. S. Evans. US, NACA TN 3860, Dec., 1956. 52 pp. 14 refs. Derivation of generalized expressions and presentation of charts for the temperature, pressure, density, and flow velocity behind a shock wave. The charts (which depend on the shock Mach Number, the initial state of the gas, and an enthalpy parameter) and an enthalpy plot for dissociated air are used to find the relation in graphical form between the degree of dissociation in air and the enthalpy parameter. Because the chemical reaction rates needed to predict the dependence of degree of dissociation on distance behind the shock are not known, order-of-magnitude estimates of their values have been used in a numerical example.

THE REFRACTION OF SHOCK WAVES AT A GASEOUS INTERFACE. R. G. Jahn. J. Fluid Mech., Nov., 1956, pp. 457-489. Shock-tube experiments using interferograms of configurations resulting from the impingement of weak and fairly strong shocks, at various angles, on interfaces between air/CO_2 and air/CH_4 to measure the strengths of the reflected waves and the angles of refraction. Measurements are compared with Polachek and Seeger's theoretical results, and good agreement is shown to exist for the so-called "regular refraction" region. "Irregular refraction" patterns are studied

qualitatively. Results indicate that these patterns are internally consistent, each representing a distortion of a regular refraction process which is reasonable under prevailing aerodynamic conditions.

PROPERTIES OF THE SHOCK TRANSITION AT LOW TEMPERATURE. J. J. Gilvarry. J. Appl. Phys., Dec., 1956, pp. 1,467--1,472. 21 refs. Formulation, in general terms, of the low-temperature thermodynamic functions of a degenerate substance possessing a zero-point pressure (or energy). The formulation is applicable to the Fermi-Dirac gas, the Thomas-Fermi atom, the Debye solid, and the Mie-Grüneisen solid as special cases. It is shown in the analysis, which follows from extension of the Bethe's method by means of Taylor's expansion of the Hugoniot function about the initial state, that Bethe's equation for the change of entropy in waves of finite amplitude is inapplicable for an initial state of temperature arbitrarily close to absolute zero, for such a substance, and that, for the same substance and initial temperature state, two of the usual four basic properties of the shock-transition under the Bethe-Weyl conditions must be modified.

ON SUPERSONIC FLOW BEHIND A CURVED SHOCK. R. E. Meyer. Australia, ARL Rep. A.98, Aug., 1956. 11 pp. Derivation of an approximate solution for the flow of an inviscid perfect gas. The method accounts for the vorticity and entropy gradients to a first approximation and is based on the assumption that a characteristic parameter, α, of homentropic theory is approximately constant along streamlines downstream of the shock. The solution of the equations of motion extends the accuracy achieved on the airfoil by shock-expansion theory to the prediction of the whole flow, represents the simplest approximation for seeking a solution to problems such as the determination of the wall shape required in the conversion of a uniform stream into a prescribed shear flow for experimental purposes, and makes it possible to obtain an experimentally adequate expression for the drag of a body in terms of the static- and stagnation-pressure distributions on a traverse.

AN INEQUALITY CONCERNING THE PRODUCTION OF VORTICITY IN ISOTROPIC TURBULENCE. R. Betchov. J. Fluid Mech., Nov., 1956, pp. 497-504. Theoretical and experimental investigation to determine the largest rate of vorticity production compatible with isotropy, homogeneity, and compressibility requirements. Analysis establishes an inequality involving the production rate S of mean-square vorticity in isotropic turbulence and a factor γ which may be said to allow for intermittency or for the nonvanishing of fourth-order cumulants. A single hot-wire anemometer is used to measure the invariants occurring in the inequality in the turbulence produced by a grid obstructing a parallel flow of air, and the resulting data - along with previous test data - are compared with the theoretical findings. Discussion of vorticity production leads to the suggestion that the most important processes associated with this phenomenon and energy transfer resemble a jet collision rather than the swirling of a contracting jet.

OUTLINE OF A THEORY OF TURBULENT SHEAR FLOW. W. V. R. Malkus. J. Fluid Mech., Nov., 1956, pp. 521-539. Analysis of the spatial variations and spectral structure of steady-state turbulent shear flow in channels, without the introduction of experimental parameters. Is is assumed that the nonlinear momentum transport has only stabilizing effects on the mean field of flow, and two constraints on the possible momentum transport are drawn from this assumption. A variational approach is described for finding the momentum-transport spectrum and mean-velocity profile leading to a marginally stable mean field of maximum dissipation rate. A first approximation to the spectrum is found and compared with experimental data.

Internal Flow

A CONTRIBUTION TO THE LATTICED WING SOLUTION (THE 14th REPORT OF STUDY OF AXIAL-FLOW TURBO-MACHINE). Shintaro Otsuka. J. Japan Soc. Aero. Eng., Oct., 1956, pp. 1-5. Method of solution is presented for a latticed wing of arbitrary profile. The profile surface is regarded as a single vortex sheet, and potential theory is applied to obtain an integral equation for the velocity potential. The solution is obtained using the method of successive approximation.

SHEAR FLOW THROUGH A CASCADE. Appendix - EFFECT OF ACTUATOR PLANE LOCATION. W. R. Hawthorne and W. D. Armstrong. Aero. Quart., Nov., 1956, pp. 247-274. Theoretical and experimental investigation of flow through a cascade of untwisted airfoils placed in a wind tunnel of rectangular section in which the approach velocity is varied artificially in the spanwise direction only. At low outlet angles or large deflections the secondary flows effectively control the downstream flow angles. When the outlet angle is large the displacement effect can result in downstream flow angles of opposite sign to those induced by the secondary flow alone. Measurements on cascade with small spanwise variations induced in the approaching stream confirm the main predictions of the theory.

ROTATING STALL IN SINGLE-STAGE AXIAL FLOW COMPRESSORS. I - COMPARISON OF THREE THEORIES WITH THREE SETS OF EXPERIMENTAL DATA. II - EXTENSION OF MARBLE'S SIMPLE CASCADE THEORY TO INCLUDE EFFECTS OF LAG. T. J. Falk. Cornell U. Grad. Sch. Aero. Eng. Rep. (AFOSR TN 56-512) [AD 110327], Sept., 1956. 67 pp. 17 refs. The three theories include Sears' airfoil and channel predictions and Stenning's and Marble's cascade theories. All of the theories predict stall-propagation speed with reasonable accuracy, and this parameter, as well as the percentage of compressor circumference stalled, is calculated by means of the extension of Marble's theory, for 10° and 30° phase lag and for three values of cascade static-pressure rise at stall.

Stability & Control

SUBSONIC WIND-TUNNEL INVESTIGATION OF THE EFFECT OF FUSELAGE AFTERBODY ON DIRECTIONAL STABILITY OF WING-FUSELAGE

COMBINATIONS AT HIGH ANGLES OF ATTACK. E. C. Polhamus and K. P. Spreemann. US, NACA TN 3896, Dec., 1956. 25 pp. Results of tests using a 4%-thick unswept wing of aspect ratio 3.0 and a 6%-thick 45° sweptback wing of aspect ratio 4.0 indicate very large differences in directional stability between the two wing-fuselage configurations: at high angles the former combination becomes stable and the latter increasingly unstable. Data from tests with the fuselage afterbody removed show that these effects are associated with wing-induced sidewash over the fuselage afterbody.

EFFECTS OF VERTICAL FINS NEAR THE NOSE OF THE FUSELAGE ON THE DIRECTIONAL AND DAMPING-IN-YAW STABILITY DERIVATIVES OF AN AIRPLANE MODEL UNDER STEADY-STATE AND OSCILLATORY CONDITIONS. M. J. Queijo and E. G. Wells. US, NACA TN 3814, Dec., 1956. 54 pp. Experimental investigation with results for angles of attack up to at least 12° indicating that fins placed above the fuselage nose decrease the directional stability but increase the damping in yaw of the model in both the steady-state and oscillatory conditions (because of the sidewash acting on the tail as well as the direct lift of the fins) and are more effective in increasing the damping in yaw than the addition of an equal amount of area at the vertical tail. Fins placed below the fuselage nose are shown to exert the same influence, to a lesser extent, on the two parameters in the steady-state condition, but reduce damping in yaw in the oscillatory condition. Results further show that placing a fin above the fuselage nose and increasing the tail size should lead to greatly increased damping in yaw for a constant value of directional stability.

THEORETICAL CALCULATION OF THE POWER SPECTRA OF THE ROLLING AND YAWING MOMENTS ON A WING IN RANDOM TURBULENCE. Appendix - EVALUATION OF THE ELLIPTIC INTEGRAL WEIGHTING FUNCTION. J. M. Eggleston and F. W. Diederich. US, NACA TN 3864, Dec., 1956. 56 pp. 17 refs. Calculation of the correlation functions and power spectra due to the three components of continuous random turbulence. The rolling moments due to the longitudinal (horizontal) and normal (vertical) components depend on the spanwise distributions of instantaneous gust intensity, which are taken into account by using the inherent properties of symmetry of isotropic turbulence. The results consist of expressions for correlation functions or spectra of the rolling moment in terms of the point correlation functions of the two components of turbulence.

FIN-AND-RUDDER LOADS IN A YAWING MANOEUVRE: EFFECT OF DIRECT AND POWER ASSISTED RUDDER MOVEMENT. D. R. Puttock. (Gt. Brit., RAE TN Struc. 169, July, 1955.) Gt. Brit., ARC CP 301, 1956. 51 pp. BIS, New York, $1.26. Investigation of the severity of a yawing maneuver as specified for design purposes. It is found that the maneuver does not always represent the most critical case, higher fin and rudder loading being obtainable when the specified frequency of rudder movement is changed. The inclusion of a power unit in the circuit may impose restrictions on the rudder movement, leading to a reduction in the severity of the loading. The analytical treatment includes the derivation of exact expressions for the angle of sideslip, fin-and-rudder load, and rudder hinge moment induced by a sinusoidal rudder movement of arbitrary frequency. These expressions are analyzed to determine how the maxima of each of the quantities are affected by variations in the frequency of the rudder movement.

Wings & Airfoils

AN INTRODUCTION TO SECOND-ORDER WING THEORY. D. C. M. Leslie. J. Aero. Sci., Feb., 1957, pp. 99-106. Application to wing theory of the Fell-Leslie integral for the iteration equation of inviscid supersonic flow in order to calculate second-order derivatives for wings of finite aspect ratio and to determine the extent to which Busemann's second-order strip theory is in error. The lift coefficient of a rectangular wing with a simple thickness distribution is used as an example. The influence of thickness on lifting derivatives is discussed and it is noted that corrections to strip theory will be largest on a wing with subsonic edges. Results further indicate that the Perry-Leslie method considerably reduces calculation labor.

THE EFFECT OF DIHEDRAL ON THE AERODYNAMIC DERIVATIVES WITH RESPECT TO SIDESLIP FOR AIRFOILS IN SUPERSONIC FLOW. J.B. L. Powell. Quart. J. Mech. & Appl. Math., Dec., 1956, pp. 425-440. Analysis in supersonic flow of a thin dihedral wing having a small velocity in sideslip. Linearized theory is used to investigate the surface pressure distribution for wings whose plan form is symmetrical about the line of undisturbed flow through the vertex. The force derivatives are determined and graphs, giving the value of these derivatives for wings of delta plan form, are presented for both cases: (a) the wing leading edges lie outside and (b) they lie inside the Mach cone from their vertex. Graphs giving the contribution from interference pressure alone are presented for other wing shapes.

ON THE THEORY OF SOURCE-FLOW FROM AEROFOILS. L. C. Woods. Quart. J. Mech. & Appl. Math., Dec., 1956, pp. 441-456. Development of an exact theoretical treatment of the influence of sources of fluid on and within two-dimensional airfoils. The theory, which takes into account the shape of a duct through which fluid is ejected in the case of a source placed within an airfoil, is given for incompressible flow but is also suitable for extension to deal with linearized, subsonic, compressible flow. Formulas for the thrust, lift, and moment are derived from Blasius' theorem; consideration is given to the case of the "directed" source; and the influence of the angle of ejection is determined.

THE MOVING AEROFOIL IN THE NEIGHBOURHOOD OF A PLANE BOUNDARY. D. E. Edmunds. Quart. J. Mech. & Appl. Math., Dec., 1956, pp. 400-424. Derivation of a solution by extension of

Green's method for a stationary airfoil in a uniform stream near a plane boundary. Results, given in series form, apply to a fairly general type of airfoil, but special attention is given to those of the flat-plate, symmetrical, and circular-arc types in order to assess the effects of thickness and camber.

EXPERIMENTAL DETERMINATION OF THE RANGE OF APPLICABILITY OF THE TRANSONIC AREA RULE FOR WINGS OF TRIANGULAR PLAN FORM. W. A. Page. US, NACA TN 3872, Dec., 1956. 22 pp. Investigation to determine the zero-lift drag rise at transonic speeds of a family of triangular plan-form wings of varying thickness and aspect ratio, mounted on a cylindrical body. Together with the transonic similarity parameters, the results of the tests are used to define the range of applicability of the transonic area rule for wings of triangular plan form. The significance of the test results is discussed.

OPTIMUM THICKNESS AND LIFT DISTRIBUTION FOR A FUSELAGE IN THE PRESENCE OF A PRESCRIBED WING SYSTEM. M. E. Graham. J Aero. Sci., Feb., 1957, pp. 142-144. 11 refs. Analysis using a drag formula of Hayes to obtain a generalized supersonic "area rule" expressed in terms of sources, lift, and side-force singularities. Includes simple examples of optimum fuselage lift distributions.

AEROELASTICITY

THE REFLECTION OF TRANSVERSE WAVES IN BEAMS. R. P. N. Jones. Quart. J. Mech. & Appl. Math., Dec., 1956, pp. 499-507. 10 refs. Derivation of a theory for determining the reflections of an incident wave at a beam end, with discussion of the propagation and reflection of a flexural pulse. The analysis is based on Timoshenko's theory of transverse vibration of beams which predicts the existence of two possible types of wave motion of given frequency: the first type is progressive for all frequencies; for the second type there is a critical frequency above which the waves are progressive and below which they are stationary. Results of the present investigation indicate that a single reflected wave exists at a simply supported end while both types of reflected waves are produced at a free or clamped end.

SOME MEASUREMENTS OF AERODYNAMIC FORCES AND MOMENTS AT SUBSONIC SPEEDS ON A WING-TANK CONFIGURATION OSCILLATING IN PITCH ABOUT THE WING MIDCHORD. Appendix A - CORRECTION OF ROOT REACTION FOR INERTIA AND AEROELASTIC EFFECTS TO DETERMINE THE TOTAL AERODYNAMIC LOAD. Appendix B - DETERMINATION OF THE AERODYNAMIC DAMPING-MOMENT COEFFICIENT. S. A. Clevenson and S. A. Leadbetter. US, NACA TN 3822, Dec., 1956. 37 pp. Experimental investigation over a reduced-frequency range from 0.050 to 0.657, a Mach Number range from 0.18 to 0.75, and a Reynolds Number range from 0.9×10^6 to 9.5×10^6. Comparisons of measured aerodynamic forces and moments and their respective phase angles acting on the wing-tank combination with those acting on the wing alone indicate that the overall lifts and moments are greater when the tank is attached. The forces on the tank alone are also compared with those predicted by the Andropolus-Chee-Targoff engine-nacelle theory, and good agreement is achieved between measured and calculated lift.

THE NATURAL FREQUENCIES OF THIN SKEW PLATES. R. K. Kaul and V. Cadambe. Aero. Quart., Nov., 1956, pp. 337-352. Calculation of the natural frequencies of thin isotropic rhombic plates with three possible combinations of boundary conditions, obtained by combining clamped-clamped and clamped-supported edge conditions. Rayleigh's energy principle is used to derive approximate frequency equations and eigenvalues for three different boundary conditions of skew plates when vibrating in certain modes, and Kato's theorem is used to estimate the accuracy of these eigenvalues. Kato's theorem is then used to determine the close lower bounds for which the upper bounds are provided by Rayleigh's principle.

EXPERIMENTAL AND PREDICTED LATERAL-DIRECTIONAL DYNAMIC-RESPONSE CHARACTERISTICS OF A LARGE FLEXIBLE 35° SWEPT-WING AIRPLANE AT AN ALTITUDE OF 35,000 FEET. S. C. Brown and E. C. Holleman. US, NACA TN 3874, Dec., 1956. 74 pp. Investigation of transient responses, recorded at various stations on the airplane, to aileron and rudder pulse-type disturbances and converted into frequency-response form. A frequency range of 0.5 to 25 radians per second is presented, which includes the Dutch roll and rolling modes, plus three structural modes. The measured frequency responses are compared with those obtained from transfer functions based on the lateral-directional equations of motion, which include first-order effects of structural deflections. Reasonably good agreement is obtained in the low-frequency range corresponding to the lateral direction modes.

DYNAMIC EQUATIONS OF DONNELL'S TYPE FOR CYLINDRICAL SHELLS WITH APPLICATION TO VIBRATION PROBLEMS. Yi-Yuan Yu. Syracuse U., Res. Inst. Mech. Eng. Dept. Rep. ME390-5610TN1 (AFOSR TN 56-526) [AD 110345], Oct., 1956. 26 pp. Derivation of two sets of equations - the first set from the Flügge equations, which neglect transverse-shear and rotational-inertia effects; the second set from equations which include these effects. Together with a previously derived set they are used to investigate the free-vibration problems of cylindrical shells with (respectively) freely supported, clamped, and flexibly supported edges. It is shown that, by using Donnell-type equations in connection with these problems, the natural frequency and mode may be calculated from separate equations and the Galerkin method may be used effectively and conveniently.

AIRPLANE DESIGN

Air Conditioning & Pressurization

A CONSTRUCTIONAL METHOD FOR MINIMISING THE HAZARD OF CATASTROPHIC FAILURE IN A PRESSURE-CABIN. Appendix I - EFFECT OF INTER-STRINGER SWELLING OF PRESSURE-

CABIN SKIN. Appendix II - WINDOW ARRANGEMENT APPROPRIATE TO THE MULTIPLE-BAND SCHEME OF CONSTRUCTION ADVOCATED IN THIS NOTE. D. Williams. Gt. Brit., ARC CP 286, 1956. 13 pp. BIS, New York, $0.36. Presentation of a design method to stop a crack, once started, from rapidly spreading and leading to a catastrophic failure of the pressure cabin. The method uses closely-spaced transverse flat bands (10 in. apart), the material for which is obtained by reducing the sheet thickness normally available for the shell walls.

Operation & Performance

AN ENERGY APPROACH TO CLIMB PERFORMANCE ESTIMATION OF A TURBO-JET TRANSPORT AIRCRAFT. Appendix I - EFFECT ON THE SLOPE OF THE CURVE OF CLIMB WEIGHT AGAINST ENERGY HEIGHT OF A CHANGE IN (a) CLIMB WEIGHT AND (b) TEMPERATURE. Appendix II - ILLUSTRATIVE EXAMPLE. R. B. Tamboli. Aero. Quart., Nov., 1956, pp. 315-336. Development of formulas to determine the time needed, distance covered, and fuel consumed during climb, based on some functions of energy height for different climb weights and temperature conditions.

SOME PERFORMANCE PROBLEMS ASSOCIATED WITH THE MACH 2 FIGHTER. J. Morris. (CAI Annual Gen. Meeting, Montreal, May 4, 1956.) Can. Aero. J., Dec., 1956, pp. 358-363. Consideration of the choice of configuration with emphasis on the influence of drag due to lift and of trim drag on the choice of wing plan form and type of longitudinal control. Analysis assumes that the aircraft will have combat altitude of 60,000 ft. and a 2g-level turn capability at combat speed, and that it will also be able to land and take off conventionally - a restriction that limits the wing leading-edge sweep to about 65° and aspect ratios to greater than 1.5. The weight variations implicit in the different configurations are studied.

COMPUTERS

LOGIC CIRCUITS FOR A TRANSISTOR DIGITAL COMPUTER. G. W. Booth and T. P. Bothwell. IRE Trans., EC Ser., Sept., 1956, pp. 132-138. Description of a group of circuits which fulfill the requirements of speed, low dissipation, size, and weight for airborne applications. These circuits will operate over the range -30° to +60°C. and actually have been operated over the range -50° to +90°C. Their dissipation places minimum requirements on power supplies, and temperature control may be achieved with only a small amount of cooling. An example is given showing that for a computer having 2,000 transistors, 800 of which are in bistable circuits, total dissipation will be less than 140 watts.

INSTRUMENTS

STUDY OF EXPLOSIVE VAPOR DETECTION. T. M. Shaw, F. K. Truby, and W. R. Wood. USAF WADC TR 56-293 (OTS, PB 121517 $6.00.) June, 1956. 265 pp. 291 refs. Survey of vapor-detection methods and instrumentation to detect rocket-propellant vapors in operational, piloted, rocket-powered aircraft. The results of the study show that no completely satisfactory principle of operation or sufficiently compact instrumentation capable of meeting specifications exists. Any immediate need for vapor detection can be met by the development of a compact type of nondispersive infrared analyzer. The radio frequency mass spectrometer may also be developed to serve on an interim basis as a satisfactory vapor-detection device, but would require more development than the infrared analyzer. Other areas of research include contact potentials, gas-phase chromatography, glow discharge phenomena, ionization phenomena, microwave spectrography, and semiconduction phenomena.

Automatic Control

THE LOGIC OF AUTOMATA. A. W. Burks and Hao Wang. U. Mich. Eng. Res. Inst. TN 2512-2-F (AFOSR TN 56-539) [AD 110358], Dec., 1956. 57 pp. 17 refs. Development of systems and techniques of mathematical logic to analyze the structure and behavior of automata. Classes of automata are distinguished: fixed and growing, deterministic, and probabilistic. Methods are presented for analyzing and synthesizing fixed, deterministic automata by four kinds of state tables. Use of these tables gives a decision procedure for determining whether or not two automaton junctions behave in the same manner. Matrix theory is applied to some of the state tables; theorems about the resulting matrices and a corresponding normal form automaton are proved. Finally deterministic automaton nets are analyzed in terms of cycles.

Flow Measuring Devices

SOME ASPECTS OF THE MEASUREMENT OF OSCILLATORY HYDRAULIC FLOW INCLUDING NONLINEAR EFFECTS. R. S. Wick. Jet Propulsion, Dec., 1956, pp. 1,078-1,083. 13 refs. Investigation of oscillatory flow in which a venturi-type flowmeter is simulated by a model capable of analysis under nonsteady flow conditions. Nonlinear effects and the effect of inertia are included in the model chosen. The basic parameter is shown to be a nondimensional frequency defined as the Strouhal Number. The errors due to neglecting inertial forces in the flowmeter model are calculated as a function of the Strouhal Number. The analysis indicates that for a venturi meter the error in average flow rate calculated (neglecting inertia) is likely to be small for practical cases. However, the phase lag and change in response (due to inertia) are likely to be important when an estimate of instantaneous flow is required.

Temperature Measuring Devices

THEORY AND DESIGN OF A PNEUMATIC TEMPERATURE PROBE AND EXPERIMENTAL RESULTS OBTAINED IN A HIGH-TEMPERATURE GAS STREAM. Appendix A, B - ESTIMATION OF EFFECTIVE SPECIFIC-HEAT RATIO. Appendix C - COOLING REQUIREMENTS. Appendix D - ORDERS OF MAGNITUDE OF POSSIBLE ERRORS. Appendix E - SAMPLE CALCULATION FOR EX-

PERIMENTAL PROBE. F. W. Simmons and G. E. Glawe. US, NACA TN 3893, Jan., 1957. 41 pp. 14 refs. Includes discussion of design requirements and operating considerations, and comparison of experimental-probe temperature measurements over a range of 1,600° to 4,000° R. in hydrocarbon gases with those obtained by thermocouples and a line-reversal pyrometer.

MATERIALS

Metals & Alloys

FATIGUE TESTS ON NOTCHED AND UNNOTCHED SHEET SPECIMENS OF 2024-T3 AND 7075-T6 ALUMINUM ALLOYS AND OF SAE 4130 STEEL WITH SPECIAL CONSIDERATION OF THE LIFE RANGE FROM 2 TO 10,000 CYCLES. Walter Illg. US, NACA TN 3866, Dec., 1956. 40 pp. Results of tests which show that repeated applications of stresses in the vicinity of the ultimate strength on notched and unnotched specimens produce failures in much smaller numbers of cycles than might be inferred from previously published data. Ratios of fatigue strengths of unnotched specimens are given.

Metal & Alloys, Nonferrous

STATIC STRENGTH AND FATIGUE PROPERTIES OF UNNOTCHED CIRCULAR 75S-T SPECIMENS SUBJECTED TO REPEATED TENSILE LOADING. Waloddi Weibull. Sweden, Flygtekniska Försöksanstalten, FFA Medd. 68, June, 1956. 29 pp. Statistical analysis of data from a series of 24 static tensile tests and 270 fatigue tests by determination of the median S-N curve, the scatter and the distribution function of the fatigue strength as well as the P-S-N equation. It was found that the scatter in fatigue strength is independent of the number of stress cycles applied and that the strength is neither normally nor log-normally distributed. The scatter due to the material is small and of the same magnitude as the scatter due to the testing machine. Formulas for calculating the variances of estimated parameters have been derived and applied to the test data.

MATHEMATICS

ON THE GENERALIZED RADIATION PROBLEM OF A. WEINSTEIN. H. M. Lieberstein. U. Md. Inst. Fluid Dynamics & Appl. Math., TN BN-87 (AFOSR TN 56-594) [AD 115021], Nov., 1956. 92 pp. 27 refs. Proof of a uniqueness theorem applicable to solutions for which a prolongation across the characteristic line $y = x$ does exist. A very large class of the Weinstein solutions are found to have this property. Analysis includes an outline of the way in which the problem considered is related to radiation.

FINITE DIFFERENCE METHODS FOR THE FIRST BOUNDARY VALUE PROBLEM OF $\Delta u(x, y) = r(x, y, u)$ AND CURVED BOUNDARIES. Werner Uhlmann. Hamburg U., AFOSR TN 56-390 [AD 96048], July, 1956. 39 pp. Development of an approximate solution of a differential equation for a given domain G of the x, y-plane which is equal to a specified function on the boundary of G. Solutions are presented using ordinary finite difference method and the Mehrstellen method. Boundary values for curved boundaries are obtained by constructing finite expressions for u in the usual way. If $r(x, y, u)$ depends only linearly on u, then the Mehrstellen method gives greater accuracy with only a small increase in labor.

EINFACHE ANGENÄHERTE BERECHNUNG DER BIEGEEIGENFREQUENZEN EINES EINSEITIG EINGESPANNTEN BALKENS UNGLEICHFÖRMIGEN QUERSCHNITTES, SOWIE DER EIGENWERTE ÄHNLICHER VARIATIONSPROBLEME. H. Wittmeyer. ZAMM, Sept.-Oct., 1956, pp. 355-367. 14 refs. In German. Transformation of the variation problem belonging to a special self-adjoint differential equation of the second order into an adequate canonic form similar to that of Hamilton-Jacobi. A first-order perturbation method is used to determine the value of the parameter in an approximating one-parametrical variation problem with constant coefficients. The exactly computable eigenvalues of this variation problem and the most favorable value of the parameter are the approximative values for the eigenvalues of the given differential equation. For the case $n=2$ a simple procedure for computing natural bending frequencies is developed.

ÜBER DAS DIFFERENZENVERFAHREN BEI NICHTLINEAREN RANDWERTAUFGABEN. I. Johann Schröder. ZAMM, Sept.-Oct., 1956, pp. 319-331. 11 refs. In German. Description of iteration methods for solving the equations of differences for boundary value problems in the case of ordinary differential equations of the second order.

PRIMITIVE OPERATORS OF DEFICIENCY (m, m). H. L. Hamburger, Arlen Brown, and Shlomo Sternberg. Chicago U., Dept. Math. TR (AFOSR TN 56-500) [AD 110315], July, 1956. 59 pp. Analysis assuming a complex Hilbert space (i.e., one that admits complex scalars) that satisfies one of the following equivalent conditions: (a) (separability) there exists a countable, everywhere dense set of vectors; (b) there exists a countable, linearly independent set of vectors whose finite linear combinations are everywhere dense; and (c) every orthonormal (ON) system is countable.

SUBHARMONIC FUNCTIONS AND GENERALIZED TRICOMI EQUATIONS. Alexander Weinstein. U. Md., Inst. Fluid Dynamics & Appl. Math., TN BN-88 (AFOSR TN 56-574) [AD 110396], Nov., 1956. 22 pp. 10 refs. USAF-supported analysis of the singular Cauchy problem for an Euler-Poisson-Darboux (EPD) equation with nonnegative index. Properties of solutions of the pertinent Cauchy problem are investigated under the assumption that the initial data satisfy a differential equation of the Helmholtz type. It is further assumed that the initial data are subharmonic or subharmonic of higher order, and the main tool used is Weinstein's transformation of the EPD equation into a generalized Tricomi equation in several variables.

METEOROLOGY

A MODEL ATMOSPHERE FOR WIDESPREAD PRECIPITATION. David Atlas and Edwin Kessler, III. Aero. Eng. Rev., Feb., 1957, pp. 69-77, 82. 13 refs. Derivation of a standard precipitation atmosphere which can be applied to problems in aeronautics and radar detection. The calculations are based on models of three cases of horizontally homogeneous air. Quantities derived include distribution of precipitation intensity with height, distribution of spatial concentration with height, liquid water content, particle size distribution, and radar reflectivity as a function of height.

MISSILES

LES ENGINS SPÉCIAUX ANGLAIS. J. Klopp. Docaéro, Nov., 1956, pp. 3-8. In French. General survey of missile production in Great Britain since 1945, with details of experimental designs, construction, and testing techniques.

ÜBER DEN EINFLUSS EINER VARIATION DER GERÄTEDATEN, INSBESONDERE DER FLÜGELFLÄCHE, AUF DIE MAXIMALE VERZÖGERUNG UND HAUTTEMPERATUR VON RÜCKKEHRGERÄTEN. H. J. Kaeppeler. ZFW, Dec., 1956, pp. 382-388. In German. Development of a simple theoretical method for estimating the effects of a variation of the design parameters of a missile on the elements of the supersonic glide trajectory. The method is based on an analytical integration of the equations of motion for the supersonic glide path of winged missiles at a constant angle of glide.

PHOTOGRAPHY

THE SIMULTANEOUS DETERMINATION OF THE ORIENTATION AND LENS DISTORTION OF A PHOTOGRAMMETRIC CAMERA. D. C. Brown. USAF MTC TR 56-20 [AD 96626], Nov. 14, 1956. 24 pp. Extension of the rigorous least-squares calibration of the orientation of a photogrammetric camera to determine additional parameters defining the radial distortion of the camera lens. Analysis shows that the major advantage of the described method consists in its ability, with normally distributed measuring errors, to yield estimates of the orientation and distortion parameters having the properties of unbiasedness, maximum likelihood, and minimum variance.

PHYSICS

THE KINETIC THEORY OF MULTI-COMPONENT SYSTEMS OF NON-SPHERICAL OR "LOADED SPHERE" MOLECULES. J. S. Dahler. U. Wis. NRL Dept. Chem. Rep. WIS-ONR-23, Dec. 13, 1956. 34 pp. Development of a kinetic theory of loaded spheres in a manner patterned on the Chapman-Enskog approach and the work of Curtiss. The problem provides a simple explanation of the enrichment by thermal diffusion of mixtures of molecular species which differ from one another only by their different internal mass distribution. It is found that the formal kinetic theory for a mixture of loaded spheres is equivalent to that for a mixture of non-spherical molecules whose centers of mass coincide with their centers of symmetry.

POWER PLANTS

Jet & Turbine

LA RENAISSANCE DU TORBOMOTEUR. M. Faury. Docaéro, Nov., 1956, pp. 37-48. In French. Evaluation of turbine power plants, their superiority over piston engines, and comparison with other types of propulsion. Application to helicopters and air transport is analyzed, and advantages for high-speed and short-take-off operations are outlined.

ÉTUDE DE PROBLÈMES DE COMBUSTION DANS LES TURBINES A GAZ D'AVIATION. J. S. Clarke. Tech. et Sci. Aéronautiques, No. 5, 1956, pp. 205-220. In French. Study of combustion problems in gas turbines. The general operating conditions, ignition, flame stabilization and heat radiation, fuel properties, carbon formation, and overall combustion-chamber design are taken into account.

RESEARCH ON APPLICATION OF COOLING TO GAS TURBINES. J. B. Esgar, J. N. B. Livingood, and R. O. Hickel. ASME Semi Annual Meeting, Cleveland, June 17-21, 1956, Paper 56-SA-54. 12 pp. 45 refs. Discussion of advantages and disadvantages in turbine cooling, and evaluation of the methods for cooling. The discussion shows that for some applications of turbine cooling, the specific fuel consumption of the engine can be improved, and will permit increased allowable stress levels. As a result, it is possible to increase the mass-flow rate through the turbine and, in all probability, the turbine can be made more reliable. However, the use of cooling introduces more complications into engine design, and for some modes of flight operation, high-turbine-inlet temperature causes poor fuel economy. Five methods of cooling are discussed, three are air-cooling and two are liquid-cooling. These include convection cooling, film cooling, transpiration cooling, spray cooling, and natural convection cooling.

HEAT-TRANSFER PROBLEMS OF LIQUID-COOLED GAS-TURBINE BLADES. Henry Cohen and F. J. Bayley. IME Proc., No. 53, 1955, pp. 1,063-1,074; Communications, pp. 1,075-1,079; Author's reply, pp. 1,079, 1,080. 11 refs. Survey of possible methods of cooling rotor blades in which it is found that the thermo-syphon system is the most effective. In this system a quantity of liquid is enclosed within each blade to act as a conveyor of heat to the more easily cooled root. Two experimental investigations of this system are described, the first using a rotating apparatus to obtain qualitative indications of the effectiveness of the system, and the second using a static rig which permits a more detailed study of the heat-transfer mechanism.

SOME EXPERIMENTS ON AN EFFUSION COOLED TURBINE NOZZLE BLADE. Appendix I, II, III - THE STATIC PRESSURE DISTRIBUTION OVER THE BLADE SURFACE AT Mn 0.24 AND 0.58. Appendix IV - PERMEABILITY DATA FOR WOVEN WIRE CLOTH AND OTHER PERMEABLE MATERI-

ALS. S. J. Andrews, H. Ogden, and Jane Marshall. Gt. Brit., ARC CP 267, 1956. 36 pp. BIS, New York, $0.90. Theoretical and experimental investigation in a cascade tunnel to determine the chordwise effusion, the flow distribution required to produce uniform surface temperature at midspan, and the temperature distribution at midspan produced by uniform effusion. Results indicate that an improvement in overall effusion-cooling performance might be obtained if the effusion flow is varied smoothly round the surface rather than in a few distinct chordwise steps and if the porous skin has a greater number of smaller, more uniformly distributed pores.

ZUR HERLEITUNG DER EULERGLEICHUNGEN DES BRACHYSTOCHRONEN ENDPUNKTGEBUNDENEN STEIGFLUGES IN VERTIKALER EBENE BEI VERSCHIEDENEN ENDBEDINGUNGEN. Hermann Behrbohm. ZFW, Dec., 1956, pp. 373-382. In German. Derivation of Euler's differential equations for the optimum rate of climb in a vertical plane for a jet-propelled aircraft operating under specified initial conditions (velocity, angle of flight path, and weight) from the origin to a given ultimate point, with the final conditions varying in accordance with the case considered. Special attention is given to the requirements of the final values of the Lagrange multiplier functions which are expressed in terms of the prescribed final conditions of the flight path. Mach Number effects on drag, Mach Number and altitude effects on thrust, and the change of weight due to fuel consumption are taken into account in a generalized form.

ANALYTICAL INVESTIGATION OF THE EFFECT OF WATER INJECTION ON SUPERSONIC TURBOJET-ENGINE - INLET MATCHING AND THRUST AUGMENTATION. Appendix A, B - CALCULATION OF ONE-DIMENSIONAL FLOW WITH COMPLETE EVAPORATION OF WATER IN A CONSTANT-AREA CHANNEL. Appendix C - ENGINE-INLET MATCHING WITH EVAPORATIVE COOLING AHEAD OF THE TURBOJET ENGINE. Andrew Beke. US, NACA TN 3922, Jan., 1957. 25 pp. Application of derived one-dimensional equations to a fixed-geometry inlet and comparison of the inlet's flight performance with that of bypass and translating-spike inlets. The investigation, performed at Mach Numbers up to 2.6 and altitudes up to 55,000 ft., serves to establish inlet-airflow variation with various liquid-air ratios, to evaluate the effect on engine-inlet matching in terms of comparative net propulsive thrust and total liquid specific impulse, and to determine the expected improvement in maximum altitude.

INFLUENCE DU NOMBRE DE REYNOLDS SUR LES PERTES DANS LES GRILLES D'AUBES. A. L. Jaumotte and Pierre Devienne. Tech. et Sci. Aéronautiques, No. 5, 1956, pp. 227-232. In French. Definitions of the loss coefficient and analysis of the influence of Reynolds Number on the loss coefficient of three types of blades - accelerating, decelerating, and relaxation blades. Results are compared with the evolution of the drag coefficient in the case of a zero incidence flat plate. It is pointed out that the Reynolds Number transition ratio is the same for a flat plate if the Reynolds Number parameter is conveniently selected.

Rocket

ON THE DEVELOPMENT OF RATIONAL SCALING PROCEDURES FOR LIQUID-FUEL ROCKET ENGINES. S. S. Penner. AMF TD TR 101 (AFOSR TN 56-383) [AD 95819], Sept. 19, 1956. 27 pp. Survey of recent theoretical studies concerning similarity analysis and the scaling of liquid-fuel rocket engines. The problem of scaling for steady internal aerothermochemistry of liquid-fuel rocket engines has been formulated by following Damkohler's procedure for chemical reactors. Control over chemical conversion rate, which is essential for engine scaling with maintenance of exact similarity, is obtained by control of droplet size through variation of the surface tension by the addition of suitable surface-active agents. Following Crocco's terminology this procedure is referred to as the Penner-Tsien (P. T.) method. The method is applicable only to bipropellant systems with greatly different volatilities.

THE USE OF SOLID PROPELLANT ENGINES FOR ACHIEVEMENT OF SUPER VELOCITIES. J. W. Wiggins. (ARS Semi-Annual Meeting, Cleveland, June 18-20, 1956.) Jet Propulsion, Dec., 1956, pp. 1,084-1,087. Review of the analytical relationships which determine the velocity of a missile, considering the effects of engine efficiency for low burned velocities and super velocities. The efficient staging for achieving velocities higher than those which can be achieved for a single stage is discussed. The basic case-bonded solid propellant and its characteristics, which provide the high performance necessary for the achievement of super velocities, are explained.

ROTATING WING AIRCRAFT

DISTRIBUTION OF NORMAL COMPONENT OF INDUCED VELOCITY IN LATERAL PLANE OF A LIFTING ROTOR. Walter Castles, Jr., and H. L. Durham, Jr. US, NACA TN 3841, Dec., 1956. 26 pp. Analysis to determine the values of the nondimensional normal component of induced velocity using the Biot-Savart relation which assumes that the wake vortex distribution consists of a uniform, semiinfinite elliptic cylinder. The necessary auxiliary equations are given so that graphs or tables of the induced velocity ratios may be used to estimate numerical values of the normal component of induced velocity and the associated flow angle in the lateral plane of any given rotor or set of laterally disposed rotors.

DETERMINATION OF THE STRUCTURAL DAMPING COEFFICIENTS OF SIX FULL-SCALE HELICOPTER ROTOR BLADES OF DIFFERENT MATERIALS AND METHODS OF CONSTRUCTION. F. W. Gibson. US, NACA TN 3862, Dec., 1956. 19 pp. Investigation to determine structural damping coefficients for the first three flapwise bending modes, the first torsion mode, and the first chordwise bending mode for all blades. The coefficients

for all blades are presented in tabular form together with the frequencies, amplitudes of oscillation, and approximate stresses in flapwise bending. Typical samples of the data are plotted to show effects of construction, mode shape, and amplitude of the structural damping coefficients. The contribution of structural damping to the total damping of the blades is discussed for several aerodynamic conditions to point out situations where structural damping is significant.

EXPERIMENTAL INVESTIGATION ON THE LANGLEY HELICOPTER TEST TOWER OF COMPRESSIBILITY EFFECTS ON A ROTOR HAVING NACA 63_2-015 AIRFOIL SECTIONS. J. P. Shivers and P. J. Carpenter. US, NACA TN 3850, Dec., 1956. 28 pp. Data on hovering performance and blade pitching moments for blade-tip Mach Numbers ranging from 0.31 to 0.71 indicate that the rotor can operate at much higher blade-lift coefficients before encountering compressibility losses than those shown in previous tests on rotors having NACA 23015 airfoil sections; that mean blade-lift coefficients of about 0.6 are reached without appreciable compressibility losses at a tip Mach Number of 0.71; and that the two-dimensional airfoil-section data provide a reasonable basis for predicting the onset of such losses and show differences in Mach Number for drag divergence between airfoils that are realized in actual rotor tests.

ON THE GENERALIZED SIMPLE SYSTEM FOR AUTOMATIC STABILIZATION OF A HELICOPTER IN HOVERING FLIGHT. M. A. P. Willmer. J. Helicopter Assn. Gt. Brit., Oct., 1956, pp. 77-102. Analysis of instability on a hovering helicopter with controls fixed. The generalized simple stabilization system which is composed of rods, springs, dampers and masses, and uses the rotor shaft to generate gyroscopic forces is studied. The results are given in terms of the automatic control component in phase with the attitude (θa), the automatic control component in phase with the rate of change of attitude (θq), and the angular velocity of the rotor. Results indicate that a helicopter can be fitted with an automatic control device utilizing the rotor shaft as the origin of gyroscopic couples to give any required stability with controls fixed. A second-order system gives the small values of the ratio $\theta q \Omega / \theta a$ required for good stability.

ANALYTICAL DETERMINATION OF THE NATURAL COUPLED FREQUENCIES AND MODE SHAPES AND THE RESPONSE TO OSCILLATING FORCING FUNCTIONS OF TANDEM HELICOPTERS. Appendix-STEPS IN REDUCING THE ORDER OF THE MATRIX EQUATION. G. W. Brooks and J. C. Houbolt. US, NACA TN 3849. Dec., 1956. 45 pp. Presentation of a method using the Lagrange dynamical equations for free vibrations in conjunction with the kinetic and potential energies of the system in order to obtain the differential equations of motion for the coupled system which are then written in matrix form. The elements of the determinant of matrix equation include the natural frequencies, mode shapes, and mass distributions of the uncoupled components of the helicopter, and permit the inclusion of experimental data of the uncoupled components in the evaluation of the coupled frequencies of the coupled system.

STRUCTURES

FATIGUE-CRACK-PROPAGATION AND RESIDUAL-STATIC-STRENGTH RESULTS ON FULL-SCALE TRANSPORT-AIRPLANE WINGS. R. E. Whaley, M. J. McGuigan, Jr., and D. F. Bryan. US, NACA TN 3847, Dec., 1956. 57 pp. Experimental investigation on nine complete C-46 wings to determine the relation of crack propagation to residual static strength. The propagation of all fatigue cracks is shown accompanied by an explanation of the progress of the crack through the elements of the structure. The actual static strength of the wings is compared with the calculated strength. The basic information is summarized in tabular form, presented graphically, and compared with other similar test data.

A SIMPLE METHOD OF MATRIC STRUCTURAL ANALYSIS. Bertram Klein. J. Aero. Sci., Jan., 1957, pp. 39-46. 51 refs. Derivation of a procedure from the analysis of certain semimonocoque structures under the assumption of uniformly composed (untapered) structural elements, some taking only axial loads and others only shear loads in the form of constant shear flows (except for triangular panels). Includes application of the method to certain two- and three-dimensional problems. Advantages of the method are: simplicity and speed of set-up; capability of yielding all deflections (and, hence, influence coefficients) and forces, without the use of quadratic energy expressions, redundant designation and "cutting", locking of joints, combining of elements, free bodies of whole cross sections, or dummy load artifice; requirement of only one combined matric equation with entries of but one number for each element in the matrix; and ability to handle easily thermal loads, mixed boundary conditions, and removal, addition, or size change of structural elements.

BEHAVIOR OF MATERIALS UNDER COMBINED STRESSES IN PRESSURIZED STRUCTURES. A. D. Topping. Aero. Eng. Rev., Feb., 1957, pp. 16 refs. Discussion of the design of pressurized cabins in which the phenomenon of brittleness due to the presence of hydrostatic tension is encountered. There are three approaches toward the solution of the minimum-weight design problem: (1) increasing basic knowledge by quantitative determination of rupture strains as a function of hydrostatic stress for each of the various structural materials; (2) refinement of current design practices as suggested by Zaustin; and (3) introduction of such nonhomogeneous structural materials as fabric or reinforced metals. Of these methods, only the second has so far been used. The third method has not been given serious consideration outside the lighter-than-air field.

FATIGUE DES STRUCTURES D'AVIONS. II - ENDOMMAGEMENT PAR FATIGUE ET RUPTURE DES PIÈCES ENTAILLÉES. W. Barrois. Docaéro, Nov., 1956, pp. 9-22. 32 refs. In French. Study

of the problem of fatigue in aircraft structures. Includes evaluation of Wöhler curves and definition of coefficients. Notch effect and the influence of coating and heat treatment are considered; mean stress and residual stress in notched parts are taken into account, and their occurrence and development are analyzed.

Cylinders & Shells

TABLES AND CURVES FOR DEFORMATIONS AND STRESSES IN CIRCULAR CYLINDRICAL SHELLS UNDER LOCALIZED LOADINGS. Joseph Kempner, James Sheng, and F. V. Pohle. J. Aero. Sci., Feb., 1957, pp. 119-129. 16 refs. OOR-supported presentation of data resulting from calculations of displacements, rotations, membrane stresses, and bending stresses corresponding to line loadings along generator segments of simply supported, thin-walled shells. These loads consist of a uniformly distributed radial load, symmetric with respect to a generator midpoint; a piecewise uniformly distributed radial load, antisymmetric with respect to the same point; and a symmetric uniformly distributed moment loading. Treatment includes description of procedures which facilitate application of data to cylinders under arbitrary radial surface loads.

THE BUCKLING OF SPHERICAL SHELLS BY EXTERNAL PRESSURE. IV. Masuji Uemura. J. Japan Soc. Aero. Eng., Nov., 1956, pp. 1-8. Analysis of two buckling problems - excluding the case of dead weight loading where the external pressure remains constant during the buckling process - by means of energy considerations. The first problem is the buckling by incompressible fluid pressure, and the second is the buckling of a partial spherical shell by compressible gas pressure, corresponding to the cases of perfectly rigid and arbitrary elastic loading machines. A second-order solution of a spherical shell is also obtained in the case where the solid angle pertaining to the buckled portion is large. The analysis is made from the equilibrium equation due to finite definition theory.

ON THE THEORY OF ANISOTROPIC SHALLOW SHELLS. S. A. Ambartsumyan. (Prikl. Mat. i Mekh., Vol. XII, 1948.) US, NACA TM 1424, Dec., 1956. 11 pp. Translation. Development of simultaneous equations for both the stress and deflection function of an anisotropic shallow shell, using the lines of curvature as coordinates of the system. The equations are reduced to a single eighth-order equation for each function.

ON THE CALCULATION OF SHALLOW SHELLS. S. A. Ambartsumyan. (Prikl. Mat. i Mekh., Vol. XI, 1947.) US, NACA TM 1425, Dec., 1956. 11 pp. Translation. Analysis of the problem of a uniform and concentrated loading on a shell bounded by a coordinate rectangle, using Vlasov's theory of shells. Two simultaneous equations for stresses and deflections are presented and simplified for application to the problem. Numerical results are also presented.

Plates

BERECHNUNG VON TEILWEISE EINGESPANNTEN RECHTECKIGEN PLATTEN BEI VORGABE VON RANDMOMENTEN. Udo Wegner. ZAMM, Sept.-Oct., 1956, pp. 340-355. In German. Analysis of an incomplete, co-orthogonal, complex system of biharmonic functions. The system is used to represent the coefficients in a closed form, similar to that of Fourier.

POSLEKRITICHESKAIA RABOTA GIBKIKH UPRUGIKH PLASTINOK. S. A. Alekseev. Prikl. Mat. i Mekh., Nov.-Dec., 1956, pp. 673-679. In Russian. Study of the behavior of elastic plates after the occurrence of stability loss due to loading. Several aspects of stability and the corresponding state of stress are determined. Includes illustrative application of the developed method to the study of postcritical operation of cylindrical, spherical, and slanted shells.

PHOTOELASTIC INVESTIGATION ON PLATES WITH SINGLE INTERFERENCE-FIT PINS WITH LOAD APPLIED TO PLATE ONLY. H. T. Jessop, C. Snell, and G. S. Holister. Aero. Quart., Nov., 1956, pp. 297-314. Investigations show that an interference-fit pin in a circular hole in a flat plate results in a reduction in the stress-concentration factor at the hole boundary. The stress-concentration factor decreases rapidly with an increase in the ratio of interference stress to applied tension, and decreases with the increase in the ratio of hole diameter to the width of the plate.

ANALYSIS OF A LOADED CANTILEVER PLATE BY FINITE DIFFERENCE METHODS. Appendix I - COMPUTATION MOLECULES. Appendix II - THE ELIMINATION OF FICTITIOUS DISPLACEMENT FROM THE BASIC DIFFERENCE PATTERNS. Appendix III - THE INFLUENCE MATRIX FOR A SQUARE CANTILEVER PLATE WITH $\nu = 0.3$. Appendix IV - THE INFLUENCE COEFFICIENTS FOR A SQUARE CANTILEVER PLATE WITH A UNIT CORNER LOAD. R. K. Livesley and P. C. Birchall. Gt. Brit., RAE TN M.S. 26, June, 1956. 24 pp. Development of the various difference patterns necessary for finite difference solution of rectangular plate problems with various boundary conditions and under various transverse loads. Includes description of the solution of one particular problem on DEUCE.

BOUNDARY-VALUE PROBLEMS OF SIMPLY-SUPPORTED ELASTIC PLATES. T. Buchwald and R. Tiffen. Quart. J. Mech. & Appl. Math., Dec., 1956, pp. 489-498. Derivation of solutions for plates in the form of half-planes and strips (including cases of isolated interior loading), and establishment of a uniqueness theorem to cover both cases.

THE DESIGN OF INTERMEDIATE VERTICAL STIFFENERS ON WEB PLATES SUBJECTED TO SHEAR. K. C. Rockey. Aero. Quart., Nov., 1956, pp. 275-296. 25 refs. Experimental investigation on stiffened web plates to obtain relationships between the size and spacing of vertical stiffeners, and the buckling stress of the stiffened web plate

when it is subject to shear. Tests are made on more than two hundred different plate-stiffener combinations. Different formulas are obtained for single and double-sided stiffeners, thus defining more clearly than hitherto the difference in the effect of the two types of reinforcements.

THE BUCKLING OF TAPERED PLATES IN COMPRESSION. Bertram Klein. Aircraft Eng., Dec., 1956, pp. 427-430. Development of a simple matric formulation for calculating the elastic buckling of a class of simply supported flat plates that are simultaneously tapered in plan form and thickness, and are subjected to biaxial loading in each direction. Design curves are presented for the special case when the thickness taper is linear and the plate material is equally stressed in the direction of this thickness taper.

Sandwich Structures

INFLUENCE OF THROUGH METAL ON HEAT TRANSFER THROUGH AIRCRAFT-STRUCTURAL-SANDWICH PANELS. J. R. Woolf and L. R. Scott. ASME Semi-Annual Meeting, Cleveland, June 17-21, 1956, Paper 56-SA-23. 16 pp. Theoretical and experimental investigation for the overall conductance of a sandwich panel having internal through metal slugs with metal skins of the same thickness on both sides. Heat transfer from one metal skin through the insulation to the other skin is approximated by use of a constant Δt mean. The derivation is for a basic configuration and the final equations must be modified for application to different configurations. Theory is extended to include a specific panel and results are obtained for a test specimen in which the effect of special splice plugs between two adjoining sections is considered.

Thermal Stress

TRANSIENT THERMAL STRESS IN A FLAT PLATE DUE TO NON-UNIFORM HEAT TRANSFER ACROSS ONE SURFACE. N. S. Heaps. Gt. Brit., ARC CP 299, 1956. 27 pp. 14 refs. BIS, New York, $0.72. Analysis in which a heat-transfer coefficient is postulated on an exposed surface. The coefficient varies inversely as the square of the distance from one of the longitudinal edges. A state of no heat transfer is postulated for the edges of the plate. Under these conditions there is a non-uniform transference of heat to the plate, giving rise to transient temperature gradients and thermal stresses within the plate. The solution in terms of Bessel functions is then used to estimate transient thermal stresses induced in an aircraft wing when suddenly acquiring high supersonic velocity. The results show that compressive stresses will develop near the leading and trailing edges, while the middle portions away from the edges will be subject to tension. For heat with a turbulent boundary layer the stresses will diminish to zero quantity, but for heating with a laminar boundary layer they will persist for a considerable time after attainment of high supersonic velocity.

ZUR NUMERISCHEN BESTIMMUNG DER WÄRMESPANNUNGEN. W. Bader. ZAMM, Sept.-Oct., 1956, pp. 331-339. 12 refs. In German. Determination of particular solutions for the Poisson equation of the displacement potential, and development of a method of solution for the displacement field that is to be superposed in order to fulfill the surface conditions. Includes application to the case of a cylinder, the ends of which are kept at constant difference of temperature and whose curved surface produces heat.

THE CALCULATION OF THERMOELASTIC BEAM DEFLECTIONS BY THE PRINCIPLE OF VIRTUAL WORK. B. A. Boley. J. Aero. Sci., Feb. 1957, pp. 139-141. USAF-sponsored study of an appropriate approximate formula, to assess its accuracy from the standpoint of a more rigorous thermoelastic solution. The formula, which is analogous to the equation $v=\int(MM_D/EI)\,dx$ of strength of materials, is evaluated with particular reference to rectangular beams under arbitrary temperature distributions.

TRANSIENT TEMPERATURE DISTRIBUTIONS AND THERMAL STRESSES IN FUSELAGE SHELLS WITH BULKHEADS OR FRAMES. J. S. Przemieniecki. J. RAeS, Dec., 1956, pp. 799-804. Theoretical investigation to simplify and generalize the analysis of the aerodynamic heating problem in fuselage structures, in order to clarify the salient features and to suggest methods to overcome adverse thermal effects. Includes discussion of the relative merits of various combinations of materials for the skin and the bulkhead diaphragm, investigation of the possible use of light-alloy bulkheads to alleviate thermal stresses, and diagrams for calculating maximum thermal stresses and stress-time variation for various rates of heat input in the fuselage skin due to aerodynamic heating.

CREEP BEHAVIOR OF STRUCTURAL JOINTS OF AIRCRAFT MATERIALS UNDER CONSTANT LOADS AND TEMPERATURES. Leonard Mordfin and A. C. Legate. US, NACA TN 3842, Jan., 1957. 53 pp. 23 refs. Results of 55 creep and creep-rupture tests and description of methods for predicting the time to rupture, the mode of rupture, and the deformation of joints in creep.

Wings

RANDOM AND PROGRAMMED LOAD SEQUENCE FATIGUE TESTS ON 24ST ALUMINIUM ALLOY WINGS. A. O. Payne. Australia, ARL Rep. SM. 244, Sept., 1956. 34 pp. Experimental investigation of the fatigue behavior of Mustang wings under repeated loading (i.e., cycling at constant amplitude) and under a random sequence of loads designed to represent the flight-load history of a transport aircraft. Results are compared with those predicted by the Cumulative Damage Theory using data from the repeated-load tests, and are also compared with those from a parallel investigation into the fatigue behavior of the structure under a programed block sequence involving three load amplitudes. This latter investigation was designed to explore the validity of a proposed airworthiness fatigue test.

A PROGRAMME FOR LOW ASPECT RATIO WING ANALYSIS. J. P. Morton. Aircraft Eng., Dec., 1956, pp. 415-418. Development of a digital-

computer program based on Schuerch's method to study the effect of variation in structural design and to provide reasonable data for preliminary stressing. The method represents an improvement over simple beam theory since the important effects of differential bending and the cross-coupling of bending and torsion are taken into account. It is assumed, however, that chordwise bending is small enough to have no serious effect on the analysis. Since the program prints the deflection and twist of a wing, valuable information is given to enable the designer to avoid structural layouts with undesirable aeroelastic characteristics.

MEASURED STRAINS IN A SWEPT TAPERED TUBE. II. G. L. Belcher. Australia, ARL Rep. SM.242, July, 1956. 28 pp. Experimental investigation to determine the stresses and strains for the cover (near the tube's root) and for the spar webs of a tube of rectangular cross section with the ribs parallel to the line of flight. Measurements are made by means of electrical strain gages at 102 points near the root of the tube, for nine different loading positions - each situated well outboard.

THERMODYNAMICS

Combustion

THE ηq METER, A RAPID INSTRUMENTAL METHOD OF COMBUSTION GAS ANALYSIS. F. H. Holderness. Gt. Brit., NGTE Rep. R.194, Nov., 1956. 52 pp. Description of the operating principles of an apparatus for gas analysis. An analysis can be completed in six to ten minutes by using a sample taken directly from a combustion chamber. Measurements are made of net carbon dioxide concentration, carbon monoxide, hydrogen, and the total carbon dioxide. The direct indicating instruments incorporated into the meter are two infrared gas analyzers for carbon dioxide and carbon monoxide measurement, and a sonic gas analyzer for hydrogen measurement. Calculations for the combustion efficiency and fuel/air mixture strength are included.

Heat Transfer

HEAT TRANSFER BETWEEN SOLID PARTICLES AND GAS IN A ROCKET NOZZLE. P. L. P. Dillon and L. E. Line, Jr. Jet Propulsion, Dec., 1956, pp. 1,091-1,097, 1,090. Method for calculating the degree of heat transfer, assuming that the system is one in which the solid particles are no larger than the mean free path of the gas carrying them. It is further assumed that the particles are in directed velocity equilibrium with the gases. Under these conditions it is possible to calculate the best transfer by using the kinetic theory of gases and a reasonable value of the thermal-accommodation coefficient.

VTOL & STOL

THE RAMPROP, A SUPERSONIC JET DRIVEN PROPELLER. Albert Gail. ZFW, Nov., 1956, pp. 341-355. Theoretical investigation of the pertinent structural and aerodynamic problems and proposal of an appropriate design for this propulsion system which consists of rotor blades driven with supersonic speed by ramjets or ramrockets at the blade tips. Analytical results indicate that the ramprop should be suitable for large convertible aircraft with VTOL capabilities which are also capable of transonic cruising flight and have a useful load capacity corresponding to conventional transport aircraft.

WIND TUNNELS & RESEARCH FACILITIES

METHOD OF CALCULATION FOR HEAT-REGENERATORS OF BLOWDOWN WINDTUNNELS. E. Van Spiegel. Netherlands, NLL TM F.190, Aug. 13, 1956. 14 pp. Calculation of the temperature distributions in a heat regenerator with flat steel plates for the case where the inlet temperature of the air decreases adiabatically. Two methods are given. One of them uses Riemann's method for hyperbolic differential equations, while in the other method the differential equations are replaced by difference equations, which are solved numerically.

AUTOMATIC INDICATING AND RECORDING DATA SYSTEMS FOR WIND TUNNELS. J. B. D'Andrea. (NATO AGARD 8th Wind Tunnel & Model Testing Panel, Rome, Feb. 20--25, 1956.) NATO AGARD Rep. 16, Feb., 1956. 39 pp. Application of a shaft analog-to-digital converter unit and a signal-damping device to an automatic data-recording system. The digital converter translates the analog instrument data signal for digital machine input, and the signal-damping device presents the average of a fluctuating data signal in a steady-state form. Data is produced in punched-card and printed form, and a teleplotter automatically plots a maximum of eight different components for wind-tunnel test point in a time period of 20 seconds.

GAS TURBINE DRIVE SYSTEM FOR WIND TUNNELS REQUIRING EXTREMELY HIGH POWER. Hans von Ohain. USAF WADC TN 55-319 (OTS, PB 121488, $0.50.), July, 1956. 10 pp. Study of the feasibility of a gas-turbine drive system for a power output of the order of one million horsepower. It is found that the development risk, time, and cost of such a drive system can be substantially reduced by applying a multiplicity of standard turbojet engines as a gas generator. A method of manifolding the individual exhaust jets into a common duct which assures the stability of the system is given. It is also shown that an impulse turbine can be designed which will satisfy the power speed requirements for driving large transonic or supersonic wind tunnel compressors.

VISUALIZATION OF LOW-DENSITY FLOWS BY MEANS OF OXYGEN ABSORPTION OF ULTRAVIOLET RADIATION. P. M. Sherman. J. Aero. Sci., Feb., 1957, pp. 93-98, 106. WADC-sponsored experimental investigation using a vacuum spectrograph-monochromator camera with a 1,470Å. radiation to photograph shock waves formed by flow over a sphere, a cone-cylinder, wedges, and a cylinder with axis aligned parallel to the direction of flow. An analytical method of determining stream density in axially symmetric flow from the absorption of radiation as indicated by the photographs is presented and the limitations of this method are discussed.

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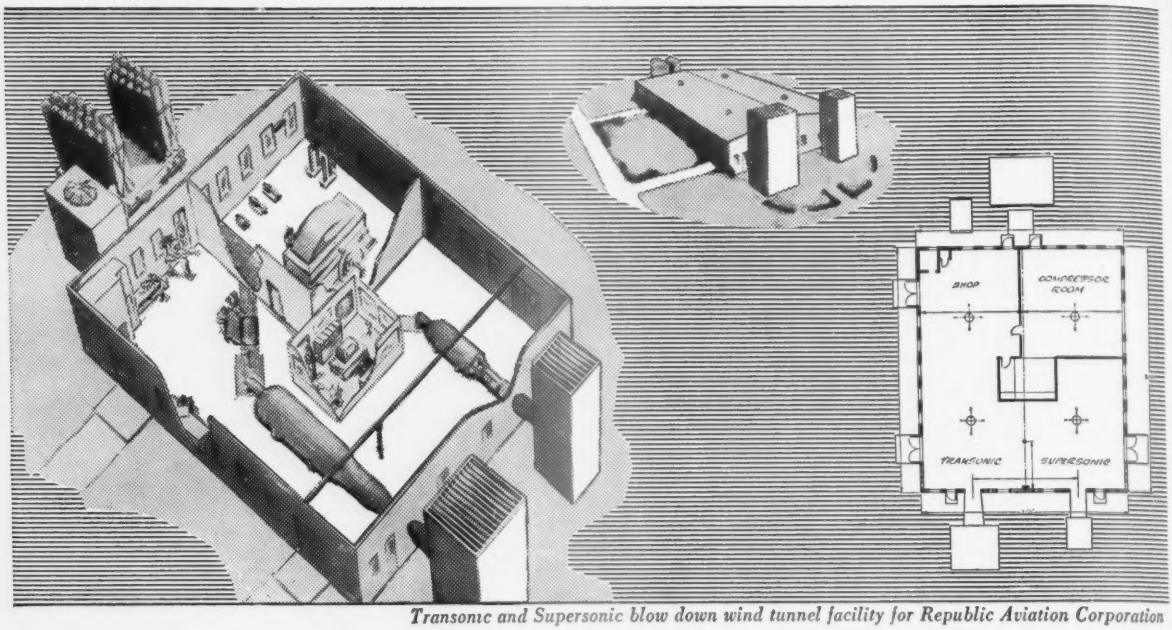

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Further Contributions to Multivariate Confidence Bounds. S. N. Roy and R. Gnanadeshikan. *N.C. U., MS 155 (AFOSR TN 56-380)* [*AD 95816*], Aug., 1956. 15 pp. Analysis of previously obtained results on confidence bounds of parametric functions connected with multivariate normal populations. Obtained are confidence bounds on characteristic roots of the population-dispersion matrix and on roots connected with two population-dispersion matrices—the regression matrix of a p-set on a q-set, and a multivariate linear hypothesis on means—including, in particular, the problem of discriminant analysis.

Mechanics

The Pressure Distribution Between Two Elastic Bodies in Contact. Harry Donald Conway. *ZAMP*, Sept. 25, 1956, pp. 460–465.

C—Mechanik. (*GAMM, Wissenschaftliche Tagung, Stuttgart, 1956.*) *ZAMM*, July-Aug., 1956, pp. 268–296. 31 refs. In German. Partial contents: Eine Bemerkung über unstetige Regelungen mit Stellungszuordnung, Johannes André. Zur geometrischen Bestimmung der Hauptschwingungsrichtungen und Eigenfrequenzen eines Systems von zwei Freiheitsgraden aus dessen Charakteristiken, A. Basch. Darstellung von Einflusszahlen in Matrizenschreibweise, W. Bauer. Die mechanische Bedeutung des instabilen Zweiges der Frequenz-Amplituden Kurve bei parametererregten Schwingungen, G. Benz. Zur rollenden Reibung zwischen Scheiben mit verschiedenen Elastizitatskonstanten, K. Desoyer. Kugelgetriebe—neue Anwendungen in Rechen- und Regeltechnik, Th. Erismann. Der schnelle symmetrische Kardankreisel mit Lagerreibung, Richard Grammel and Hans Ziegler. Gleichgewicht und Verträglichkeit in der Schalenbiegetheorie, W. Günther. Über den Einfluss einer Endmasse und Endfeder auf die Frequenz-Amplituden-Abhängigkeit längserregter Saitenquerschwingungen, H. Heidenhain. Kreiseleigenschaften des umlaufenden Kettenringes, K. Magnus. Der axial pulsierend belastete Stab mit Endmasse, E. Mettler and F. Weidenhammer. Spannungsoptische Untersuchungen von Platten mit veränderlicher Dicke, H. Schwieger and G. Haberland. Über unstetige Regelungen dynamischer Systeme mit mehreren Freiheitsgraden, Peter Seibert. Lange Zylinderschale mit nicht achsensymmetrischer Randbelastung durch Kräfte in Zylinder-Längsrichtung, G. Sonntag. Einfluss der Schubverzerrung auf die Eigenschwingungen von Platten, W. Wallisch. Torsionsbeulung eines Plattenstreifens, I. E. Weinel. Symposium of papers covering unsteady controls with positional action, geometrical determination of the principal directions of vibration and eigenfrequencies of a system with two degrees of freedom, representation of influence coefficients in matrix notation, mechanical significance of the unstable branch of the frequency amplitude curve in multiparameter forced oscillations, rolling friction between disks with different elasticity constants, new applications in computing and control techniques of ball

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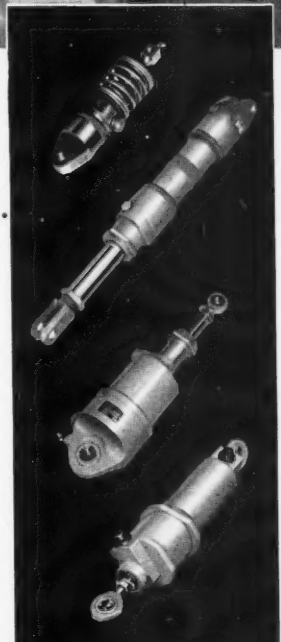

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drives, rapid symmetric and gyro with bearing friction, equilibrium and bearing capacity in the shell bending theory, influence of the end mass and end spring on the frequency-amplitude relationship of a longitudinally excited oscillating rope, gyroscopic properties of running chain rings, rods with end mass under axial pulsating loading, photoelastic investigations of plates with variable thickness, unsteady controls of a system with several degrees of freedom, long cylindrical shells with unsymmetrical edge loading due to forces along the cylinder axis, effect of shear distortion on the eigenvibrations of plates, and torsional buckling of flat strips.

Meteorology

Estimating Vorticity Advection. Robert C. Bundgaard. *Bul. AMS*, Nov., 1956, pp. 465–472. USAF study of a method involving the inspection of ordinary upper tropospheric maps and consideration of some idealized examples relating the vorticity advection to the ordinary upper-air maps from which it is derived. Includes comparison of two independent procedures for mapping both the geostrophic and the actual vorticity advections from the independent variables which have already been represented on the map. The synoptic distribution of overcast cirrostratus is also observed.

Experiments Using Window to Measure High-Altitude Winds. Albert D. Anderson and Walter E. Hoehne. *Bul. AMS*, Nov., 1956, pp. 454–457. Naval Research Laboratory tests in which strips of metal foil (window), dispersed by balloon and aircraft, are tracked by radar to measure wind velocities up to 74,000 ft.

Instantaneous and Continuous Wind Measurements up to the Higher Stratosphere. Gerhard H. R. Reisig. *J. Meteorology*, Oct., 1956, pp. 448–455. Development of a method for measuring the wind velocity encountered in guided-missile flight.

Characteristics of the Low-Level Jet Stream. H. Arakawa. *J. Meteorology*, Oct., 1956, pp. 504–506.

On the Flux of Eddy Energy in Small-Scale Turbulent Motion. Warren A. Dryden. *J. Meteorology*, Oct., 1956, pp. 433–447. 20 refs. USAF-sponsored research including a discussion of experiments on axially symmetric, low-speed, free jets of air, and application of obtained data to an idealized model for simplifying the relative flux study.

Sulla Variazione con la Quota del Parametro l^2 in Situazioni di Onde da Rilievo. Adriano Gazzola. *Riv. Meteoroligia Aero.*, July-Sept., 1956, pp. 21–30. In Italian. Analysis of the problem of atmospheric waves as related to gliding, and description of the l^2 parameter as a function of height for the cases of specific wave manifestations, with the emphasis on the importance of the shear term in comparison with the stability term.

The Development and Masking of Charges in Thunderstorms. Joachim Kuettner. *J. Meteorology*, Oct., 1956, pp. 456–470. 26 refs. Theoretical investigation of the sedimentation process including analysis of the development of charges on solid precipitation in a supercooled water cloud, the purpose of which is to illustrate the masking process, for which quantitative estimates are made on the basis of precipitation mechanisms.

On the Dynamics of Hurricanes. I—The Eye of the Hurricane. II—The Vibrations of a Hurricane. Abdul Jabbar Abdullah. *NYU Coll. Eng. Met. Papers No. 2*, Sept., 1953. 43 pp. 27 refs. Tentative evaluation of the eye of the hurricane by hydrodynamical reasoning and derivation of hydrodynamic equations for the equivalent incompressible atmosphere.

Further Evidence of Dynamic Persistence and of Its Application to Foreshadowing. Irving I. Schell. *J. Meteorology*, Oct., 1956, pp. 471–481. 11 refs. USAF-supported detailed data on the relationship of the winter and preceding fall pressure in the Philippines and adjacent areas with the winter precipitation of the North Pacific and North America. Includes examination of several dynamic-persistence relationships during the 17-year period from 1939–1940 and 1955–1956.

The Prediction of General Quasi-Geostrophic Motions. J. G. Charney, Bruce Gilchrist, and F. G. Shuman. *J. Meteorology*, Oct., 1956, pp. 489–499. 11 refs. USAF-ONR-supported description of methods for the numerical integration of several general approximations to the quasi-geostrophic equations of motion.

On the Association of Solar Radio Emission and Solar Prominences. J. P. Wild and H. Zirin. *Australian J. Phys.*, Sept., 1956, pp. 315–323. USAF-supported research.

Military Aviation & Armament

Air Force Logistics. Allen R. Ferguson. (*IAS Natl. Summer Meeting, Los Angeles, June 18–21, 1956, Preprint 647.*) *Aero. Eng. Rev.*, Jan., 1957, pp. 40–46.

RCAF Test and Development. Owen B. Philp. *IAS-CAI Internatl. Meeting, Toronto, Nov. 26, 27, 1956, Preprint 658.* 7 pp. Members, $0.35; nonmembers, $0.75. Discussion covering the history of RCAF test and development, its role, organization, test-flying activities, and its relationship with the Canadian aircraft industry.

New Organizational Alignments in the Bureau of Aeronautics. James S. Russell. *Aero. Eng. Rev.*, Jan., 1957, pp. 47, 48.

Operations Research and the Canadian Aircraft Industry. W. R. Hossack. *Can. Aero. J.*, Nov., 1956, pp. 314–316. Discussion of operations research as a means of optimizing the use of the funds required to design and build aircraft for specific purposes. Both military and civil applications are included.

Missiles

The Technology of Guided Missiles and its Effect on Industry. R. D. Richmond and J. F. Perrier. *IAS-CAI Internatl. Meeting, Toronto, Nov. 26, 27, 1956, Preprint 657.* 14 pp. Members, $0.50; nonmembers, $0.85. Evolution of the guided missile and discussion of some of the fundamentals of such weapons systems which are of particular interest to industry.

Les Engins Spéciaux Soviétiques. D. Laurent. *Docaéro*, July, 1956, pp. 3–12. In French. Presentation of data on missile development in the USSR.

Soluzioni Discontinue nei Problemi di Volo Ottimo. Placido Cicala. (*Atti Accad. Sci. Torino, 1955–1956.*) *Torino Polytech. Inst. Aero. Lab. Monograph 387*, 1956. 19 pp. In Italian. Derivation of discontinuous solutions to optimum flight problems.

Defence Against the ICBM. II. I. J. Billington, A. L. Cole, and B. S. Lamb. *The Aeroplane*, Nov. 2, 1956, pp. 662–665. Discussion which concludes that a defense is both practical and feasible against an ICBM over a specific target area by using an antimissile missile (AMM).

The Motions of Rolling Symmetrical Missiles Referred to a Body-Axis System. Robert L. Nelson. *U.S., NACA TN 3737*, Nov., 1956. 51 pp. Development of a technique for reducing rolling-missile oscillation data and application of the method to results obtained from a flight test of a missile configuration.

Navigation

A—Simulation, Tirey K. Vickers. **B—Air Traffic Control Coordinating Equipment,** G. E. Fenimore. **C—The Air Traffic Control Radar Beacon System,** D. S. Crippen. **D—Airways Operations Evaluation Center,** F. S. McKnight. *RTCA Assembly Fall Meeting, Indianapolis, Oct. 22, 23, 1956, Paper 185-56/AS-176.* 80 pp.

Electronic Aids

Storage Tube Projects Radar ppi Display. Harry W. Gates. *Electronics*, Dec., 1956, pp. 172–175. Description of a remote ppi indicator which uses a high-brightness projection tube with controllable long-time storage to provide a 50-in. display for air-traffic-control systems.

Operational Use of Tacan. Murray Block. *IAS-CAI Internatl. Meeting, Toronto, Nov. 26, 27, 1956, Preprint 653.* 5 pp. Members, $0.35; nonmembers, $0.75. Discussion of the operation and capabilities of the Tacan system, which can produce continuous and accurate position information for aircraft operation and air traffic control.

Traffic Control

The Role of Communication in Air Navigation and Traffic Control. Nathaniel Braverman. *Navigation*, Sept., 1956, pp. 133–137. 16 refs.

The Airport and Airways Surveillance Radar for Canadian Air Traffic Control. Bruce I. McCaffrey. *IAS-CAI Internatl. Meeting, Toronto, Nov. 26, 27, 1956, Preprint 655.* 20 pp. Members, $0.50; nonmembers, $0.85. Discussion of AASR in terms of its performance, reliability, ease of maintenance, and long life with continuous operation.

Pictorial Air Traffic Display Could Alert Pilot to Potential Collisions. Jacques de Vienne. (*SAE Natl. Aero. Meeting, New York, Apr., 1956, Paper.*) *SAE J.*, Nov., 1956, pp. 38–41.

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Nuclear Energy

Controlled Development for Nuclear Emulsions. Jacques M. Blum. *Rev. Sci. Instr.*, Nov., 1956, pp. 938, 939. OSR-supported research for obtaining a reproducible degree of development of nuclear emulsions at some prefixed level of sensitivity, and presentation of method consisting of separating the active phase of the development of nuclear emulsions into two or more stages.

Parachutes

Sky Diving. R. L. Oakley. *Aero. Eng. Rev.*, Jan., 1957, pp. 56, 57. Evaluation of the technique of sky-diving body control to prevent flat spins in which the body rotates about a vertical axis in a horizontal position.

Photography

Über die Genauigkeit der Luftphotogrammetrie. B. Hallert. *Acta Polytechnica*, No. 99 (194), 1956. 58 pp. 11 refs. In German. Discussion of the treatment of systematic and accidental errors in photogrammetric operations. The problem of the adjustment of the relative orientation under different conditions is also treated.

Physics

Gas Purity of High-Temperature, High-Pressure Electrical Discharges in Air. Daniel E. Bloxsom. *USAF AEDC TN 56-15* [*AD 98977*], Nov., 1956. 17 pp. Investigation of the contamination of air which results from electrical arc discharge. The results of these tests indicate that air heated by this method is contaminated by some impurities from the walls and electrodes but contains less than 1 per cent of frozen-in nitric oxide.

Investigation of the Conditions in the Plasma in Mercury-Vapor Arc Discharges and Oscillating Electron Ion Sources. Max Hoyaux and Paul Gans. *Ateliers Construc. Elec. Charleroi Rep. EOARDC TR 54* (*AFOSR TR 56-23*) [*AD 88353*], 1956. 51 pp. 25 refs. Theoretical and experimental study of the behavior of mercury-vapor arc discharges (a) at high current intensities and (b) at very low pressures, and of their dynamic behavior in fluorescent-type tubes.

Experimental Study of the "Hash" in a Fluorescent Tube. I. Appendix—**Experimental Determination of Electron Temperature.** Max Hoyaux and Paul Gans. *Ateliers Construc. Elec. Charleroi Rep. EOARDC TN 55-7* (*AFOSR TN 56-231*) [*AD 88040*], 1956. 23 pp. Description of tests using the high-resolution plasmograph.

A Study of the Hash in Fluorescent Tubes by Means of an Auto-Synchronized Plasmograph. Max Hoyaux and Paul Gans. *Ateliers Construc. Elec. Charleroi Rep. EOARDC TN 55-9* (*AFOSR TN 56-347*) [*AD 95433*], 1956. 73 pp. Results of experiments to determine the probe characteristics in the vicinity of the anode in a direct-current discharge in a cylindrical tube of a type similar to those used in fluorescent lighting. These results are compared with data from confirmatory experiments with alternating discharges.

Equations of Similitude for a Discharge in an Argon-Mercury Mixture. Max Hoyaux and Paul Gans. *Ateliers Construc. Elec. Charleroi Rep. EOARDC TN 55-10* (*AFOSR TN 56-233*) [*AD 88352*], 1956. 31 pp. Theoretical study of conditions in which the equations of similitude, previously found for the case of mercury-vapor arcs at moderate current intensities, are found to remain qualitatively valid for the case of an arc striking in an argon-mercury mixture such as exists in fluorescent tubes.

An Auto-Synchronisation System for the Plasmograph. Max Hoyaux and Paul Gans. *Ateliers Construc. Elec. Charleroi Rep. EOARDC TN 55-8* (*AFOSR TN 56-232*) [*AD 88351*], 1956. 17 pp. Development of an autosynchronization system for the plasmograph which enables the instrument to be triggered by a pulse derived from oscillations in the discharge itself rather than from the a.c. main supply.

Power Plants

Closed Cycle Aircraft Propulsion Systems. R. Tognoni and W. Spillmann. *Escher Wyss Rep. Sp.-AK-56-027, vol.I, II* (*AFOSR TR 56-45; TR 56-46*) [*AD 97087; AD 97088*], July 21, 1956. 47; 162 pp. Investigation of a closed-cycle gas turbine driving one or several ducted fans. Three possible gas-heater arrangements are considered: (a) an air heater built into the combustion chamber of a jet engine, (b) a heater built into the afterburner downstream to the ducted fan, and (c) a gas cycle nuclear reactor. The gas cooler is in the ducted-fan airflow in all cases. Also investigated are the driving of boundary-layer suction fans and the feasibility of a closed-cycle high-altitude aircraft accessory power plant.

Wake Stream Acceleration. A. Burgdorfer. *Escher Wyss TN 1, vol. III, Rep. Spn-AK-56-029* (*AFOSR TR 56-47*) [*AD 97089*], July 21, 1956. 56 pp. Theoretical investigation of the gain of a wake-stream acceleration propulsion plant to a normal unit for nondissipative machines and for flight bodies which have a symmetrical rotation structure.

Atomic

Nuclear Propulsion for Aircraft. *The Aeroplane*, Nov. 9, 1956, pp. 686, 687. (Also in *Flight*, Nov. 9, 1956, p. 771.) Basic principles of nuclear reactors are discussed, and an application to aircraft propulsion is outlined.

Jet & Turbine

Development of Rolls-Royce Propeller Turbine Engines. D. P. Huddie. (*SAE Natl. Aero. Meeting, New York, 1956, Paper.*) *Shell Av. News*, Oct., 1956, pp. 16–20.

Application of the Closed Cycle Principle to Aircraft Auxiliary Power Plants—Cooling Problems. W. Spillmann. *Escher Wyss TN 4, vol. V, Rep. Sp-AK-56-025* (*AFOSR TR 56-49*) [*AD 97351*], July 21, 1956. 23 pp. Analysis of the cooling problems encountered in a closed-cycle gas turbine. The closed cycle must have a circuit cooler for cooling down the turbine exhaust to the compressor inlet. In a recuperator cycle, a precooler at the compressor inlet is necessary. The skin temperatures are calculated from the ram temperature using a recovery factor without evaluation of the actual radiation equilibrium temperature of the flying body.

Sapphire 7; Armstrong Siddeley's Fine Turbojet Further Developed. *Flight*, Nov. 9, 1956, pp. 756–760, cutaway drawings.

Groupes Auxiliaries Turbo-Electriques. Henry Lanoy. *Docaéro*, Sept., 1956, pp. 19–44. In French. Description of compressors, combustion chambers, turbines, electric power generators, regulators, servocontrols, and other components, taking into account such characteristics as thrust, weight, and size. Curves and specific details are given of the performance of French, American, and British auxiliary air-borne and ground equipment.

Tendances Générales en Matière de Turboréacteurs et Turbopropulseurs; Réalisations des Divers Pays. K. von Gersdorff. *Docaéro*, Sept., 1956, pp. 3–18. In French. Graphical data on types, output, consumption, and weight of turbojets and turboprops.

Reaction Propulsion of Aircraft. Luigi Stipa. (*Italian Soc. for the Advancement of the Sci.*, Vol. 15, 1949.) *Miss. State Coll., Aerophys. Dept.*, Aug. 23, 1956, Reprint. 3 pp. Translation. Description of a reaction thermopropulsor giving its characteristics and advantages in comparison to gradual combustion types.

Choice of Design for an Advanced Turbojet. F. H. Keast. *Can. Aero. J.*, Nov., 1956, pp. 322–328. Discussion of such factors as design pressure ratio and turbine temperature and size in order to assess the effect of these design variables on engine weight and frontal area.

Design and Qualification Testing of High-Pressure, High-Velocity Aircraft Duct Systems. D. W. Fentress. *Aero. Eng. Rev.*, Jan., 1957, pp. 49–53. Discussion covering duct configurations, accommodating motion, metals used in duct systems, the evolution of testing and associated problems, and the need for testing that is environmental in character. Includes an illustrative description of an actual qualification test on a complete duct system.

Factors Governing the Performance of Aircraft Fuel Booster Pumps. F. E. Smith and J. F. Urich. *Thompson Prod. Eng. Bul.*, Nov., 1956, pp. 1–12. Description of some of the basic problems of fuel handling, especially at high altitudes, and presentation of some methods for analyzing and solving them.

Some Aspects of Turbojet Performance Calculation at High Flight Mach Numbers; Problems of Performance Prediction in Truly Supersonic Engines. J. R. Palmer. *Aircraft Eng.*, Nov., 1956, pp. 376–380.

A Method for Evaluating Jet-Propulsion-System Components in Terms of Missile Performance. Roger W. Luidens and Richard J. Weber. *IAS-CAI Internatl. Meeting, Toronto, Nov. 26, 27, 1956,*

Preprint 656. 11 pp. Members, $0.35; nonmembers, $0.75. Description of a simple technique, capable of handling any components of the installed engine, for estimating missile performance when only the component performance is known. Consideration is given primarily to engine air inlets and exhaust nozzles. Includes discussion of examples illustrating the method.

Analysis of the Temperature Field in a Gas-Turbine Rotor, Using a Hydraulic Integrator. E. I. Molchanov. (*Teploenergetika*, Jan., 1956, pp. 53–57.) *Engr. Dig.*, Nov., 1956, pp. 469–471, 474. Investigation of the Lukyanov hydraulic integrator consisting of a network of vessels of adjustable capacity and pipes of adjustable resistance to hydraulic flow. Application is made to a five-stage drum-type turbine rotor.

Fluid Motors Combine with Analog Computer to Test Jet Controls. Robert G. Butterwick. *Appl. Hydraulics*, Nov., 1956, pp. 119, 120. Discussion of the testing of automatic controls in which an analog computer is used to simulate the operation of a jet engine.

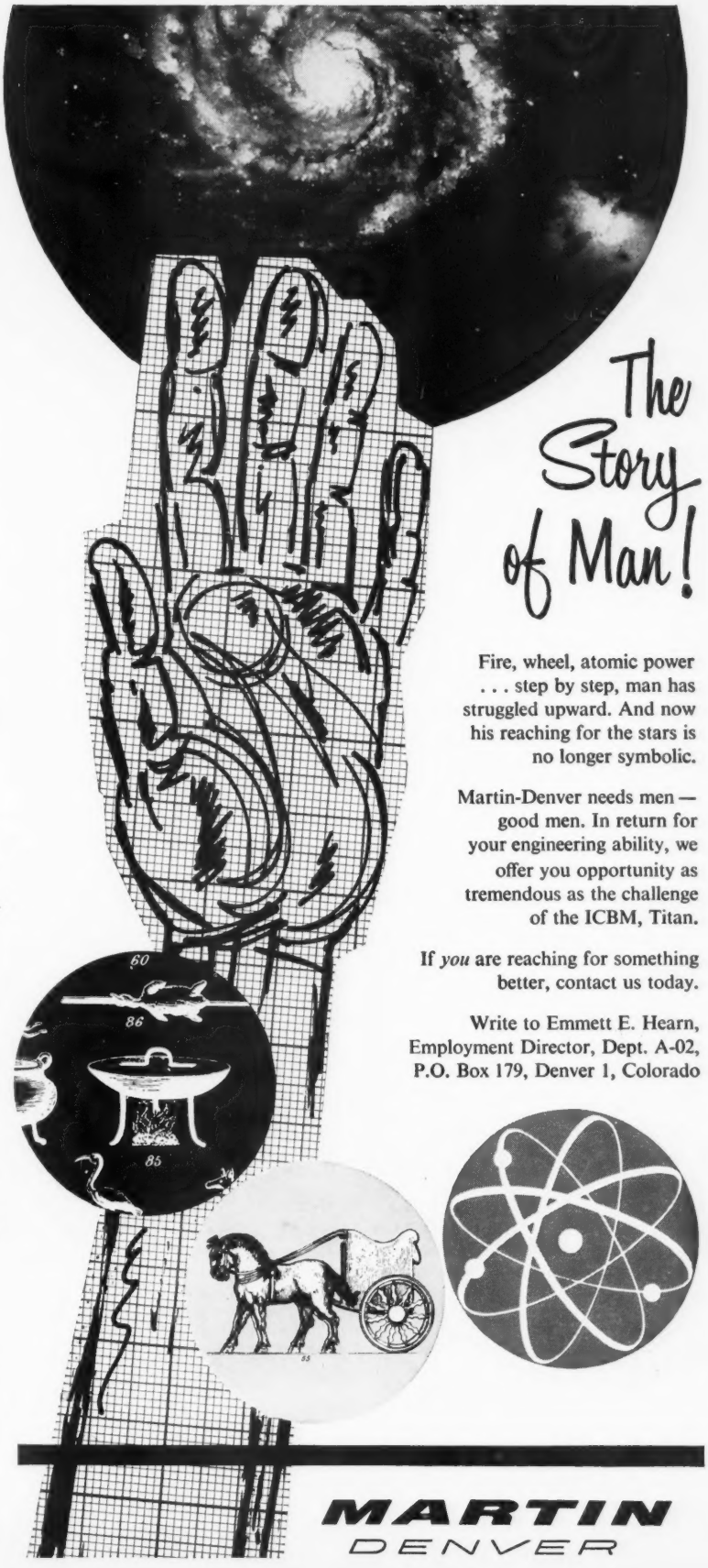
Quelques Aspects de la Fabrication des Aubages de Turbomachines aux Etats-Unis et en Grande-Bretagne. V. Berretta. *Docaéro*, July, 1956, pp. 23–48. 25 refs. In French. Analysis of some aspects of turbine blading fabrication in the United States and in Great Britain.

The Thermodynamics of Cooled Turbines. I—The Turbine Stage. II—The Multistage Turbine. W. R. Hawthorne. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *Trans. ASME*, Nov., 1956, pp. 1,765–1,785; Discussion, pp. 1,785, 1,786. 11 refs. Derivation of simple expressions for (1) the amount of heat abstracted in a cooled row of blades and (2) the drop in turbine-stage efficiency resulting from cooling. A chart is presented for rapid computation of the reheat factor and the turbine efficiency as calculated from the stage efficiency for an uncooled turbine and for one in which the blades are cooled.

Analysis of the Effect of Blade Cooling on Gas-Turbine Performance. Appendix I, II—**Analysis of Coolant Flow in Rotor and Blades; Forced-Convection Air-Cooled Power Plant.** Appendix III—**Derivation of Expression for Enthalpy Loss Due to Mixing ($\Delta H/W_A$) in Forced-Convection Air-Cooled Power Plant.** Appendix IV—**Derivation of Equations for Rotor Pumping Work.** Appendix V, VI—**Analysis of Water-Cooled Power Plant.** J. C. Burke, B. L. Buteau, and W. M. Rohsenow. (*ASME Diamond Jubilee Annual Meeting Chicago, Nov. 13–18, 1955.*) *Trans. ASME*, Nov., 1956, pp. 1,795–1,806.

Methods for Measuring Temperatures of Thin-Walled Gas-Turbine Blades. Francis S. Stepka and Robert O. Hickel. *U.S., NACA RM E56G17*, Nov. 2, 1956. 25 pp. Comparison of two methods, one employing thermocouples cemented in small grooves and the second involving the application of commercial temperature-indicating paints to the blade surfaces.

The Self-Excited Vibration of Axial-Flow Compressor Blades. A. D. S. Carter and D. A. Kilpatrick. *Chartered*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Mech. Eng., Nov., 1956, pp. 464–466. Abridged.

Ram-Jet & Pulse-Jet

A Theory for Stability and Buzz Pulsation Amplitude in Ram Jets and an Experimental Investigation Including Scale Effects. Robert L. Trimpi. *U.S., NACA Rep. 1265*, 1956. 24 pp. Supt. of Doc., Wash., $0.25.

Reciprocating

Der Ungleichförmigkeitsgrad von dieselelektrischen Aggregaten bei Berücksichtigung der Wellenelastizität. B. Will. *Forschung Gebiete Ing., Ausg. A*, No. 5, 1956, pp. 167–177. In German. Calculation of the coefficient of cyclic variation of reciprocating engines under the assumption of the shaft elasticity.

Centaurus 373. *Flight*, Nov. 16, 1956, pp. 790, 791. Description of the Bristol reciprocating engine modified to use direct fuel injection for increasing power and reliability.

The Alvis Two-Row Radial. *The Aeroplane*, Nov. 2, 1956, pp. 654, 655, 658, 659; cutaway drawing. Performance and design characteristics of the Alvis Leonides Major 14-cylinder supercharged engine. Details are given for the reduction gear and torquemeter, the power section, supercharger and accessory drives, and ignition and lubrication systems.

The Supercharged-and-Intercooled Free-Piston-and-Turbine Compound Engine; A Cycle Analysis. A. L. London. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *Trans. ASME*, Nov., 1956, pp. 1,757–1,762; Discussion, pp. 1,762–1,764.

Rocket

Dynamic Stability of Rocket Powerplants Using Liquid Propellants. Rudolf H. Reichel. *Aero. Dig.*, Nov., 1956, pp. 20, 22, 24–32 ff. Analysis of overall power-plant dynamic behavior to present various criteria for the design of stable systems, and presentation of experimental stability investigations suitable for development and production work.

A Solid-Liquid Rocket Propellant System. George E. Moore and Kurt Berman. (*ARS Semi-Annual Meeting, Cleveland, June 18–20, 1956.*) *Jet Propulsion*, Nov., 1956, pp. 965–968. Description of a self-igniting hybrid rocket-propellant system employing 90 per cent hydrogen peroxide as the oxidizer and polyethylene as the fuel, and discussion of data from tests using one type of fuel charge.

An Extension of the Theory of the Optimum Burning Program for the Level Flight of a Rocket-Powered Aircraft. Appendix A—Variation of the Lagrange Multipliers λ_1 and λ_2 Along the Constant Thrust Sub-Arcs of the Eulerian Solution. Appendix B—Analysis of Discontinuous Solutions in the Light of the Corner Conditions. Angelo Miele. *Purdue U., Sch. Aero. Eng. Rep. A-56-1 (AFOSR TN 56-302) [AD 90015]*, June, 1956. 61 pp. Investigation of a burning program which minimizes an arbitrary function of the final values of time, mass, distance, and velocity.

Production

Modern Aircraft Geometry; A Description of the Mathematical Method Used at SAAB, Sweden, for Aircraft Dimensioning and Shape Determination. N. Lidbro. *Aircraft Eng.*, Nov., 1956, pp. 388–394.

Metalworking

A Slip Line Field for the Hot Rolling Process. J. M. Alexander. *IME Proc.*, No. 50, 1955, pp. 1,021–1,028; Communications, pp. 1,029, 1030; Author's reply, p. 1,030.

Design and Production of Aluminum Castings. G. W. Birdsall. *Aero. Dig.*, Nov., 1956, pp. 13–19.

Selection of Testing Locations in Aluminum Die Forgings. Ihor E. Suchoversky. *Aero. Eng. Rev.*, Jan., 1957, pp. 29–34.

Extrusion of Metals; A Simple Theory of the Criteria of Press Design and Extrusion Efficiency in the Industrial Extrusion of Metals. P. Feltham. *Metal Treatment*, Nov., 1956, pp. 440–444. 11 refs.

Stretch Forming Under Fluid Pressure. P. B. Mellor. *J. Mech. & Phys. Solids*, Nov., 1956, pp. 41–56. 12 refs. Experimental investigation into the hydrostatic bulging of circular metal diaphragms in order to study the development of strain and of instability and to derive strain-hardening characteristics for each of the materials tested.

Production Engineering

Crack Detection in Aircraft Structures. W. Deck. *J. RAeS*, Nov., 1956, pp. 739–748. Discussion of production and maintenance inspection methods to determine cracks in castings and in forgings and service fatigue cracks. Methods described are the penetrant, magnetic, electrical conductivity, X-ray, and ultrasonic.

Quality Control Policy in the Royal Canadian Air Force. Robert McMillan. *IAS-CAI Internatl. Meeting, Toronto, Nov. 26, 27, 1956, Preprint 651.* 7 pp. Members, $0.35; nonmembers, $0.75. Discussion giving a description of functions and policies of quality control for the RCAF. Quality control involves three phases: inspection, prevention, and assurance. The first two functions are performed by the industry and the latter function by the RCAF.

Welding

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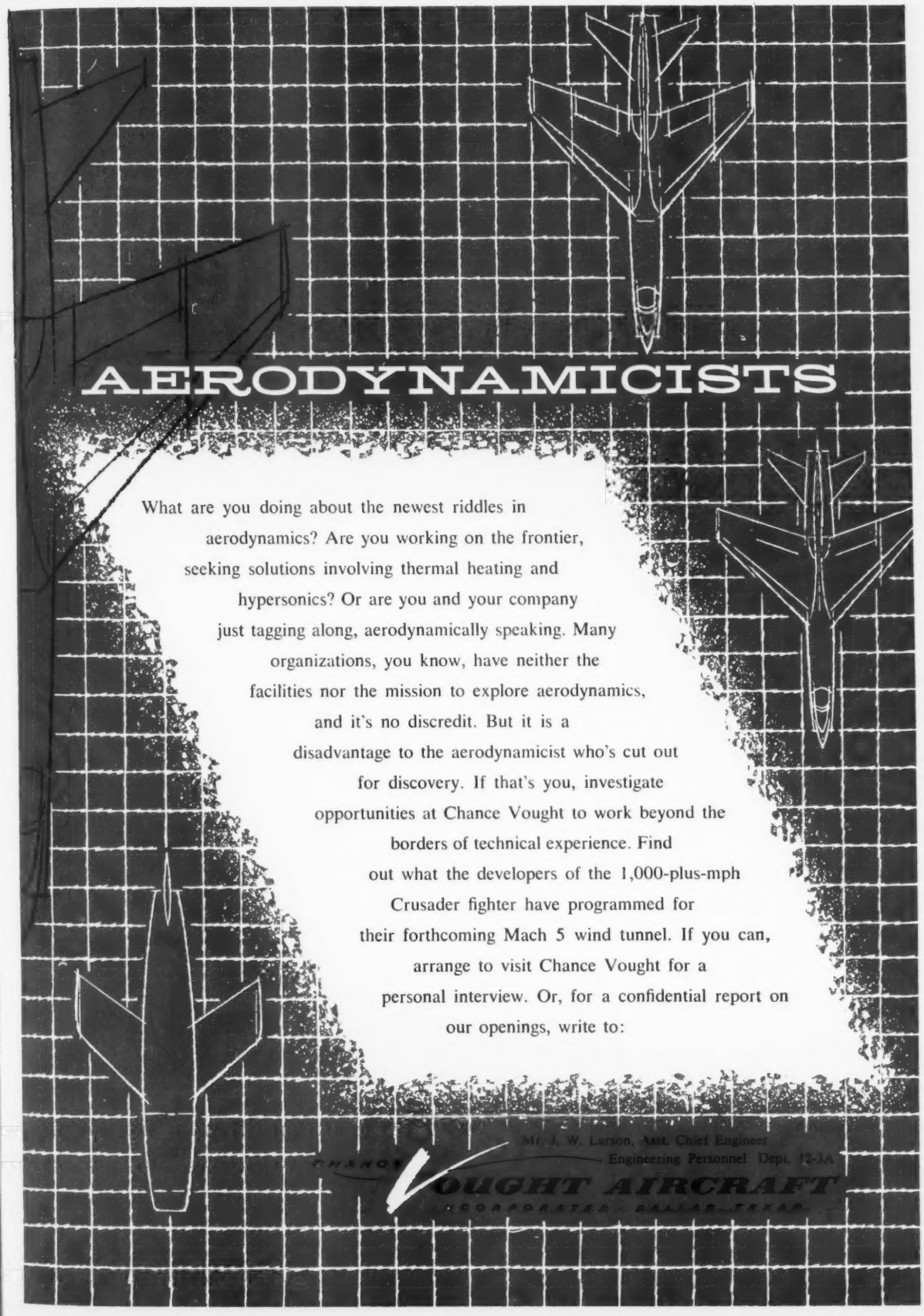
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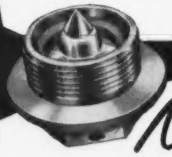

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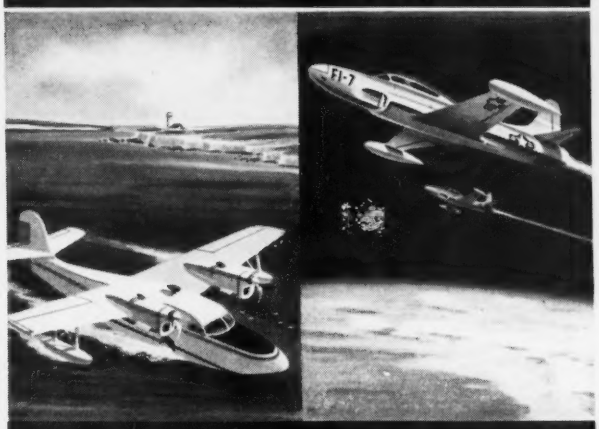

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Modified Correlation Formulae for the Heat Transfer by Natural and by Forced Convection from Horizontal Cylinders. B. G. Van Der Hegge Zijnen. *Appl. Sci. Res., Sect. A*, No. 2–3, 1956, pp. 129–140. 28 refs.

Laminar-Free-Convection Heat Transfer from the Outer Surface of a Vertical Circular Cylinder. Appendix A, B—**Analysis Based on Equivalent Conducting Layer.** E. M. Sparrow and J. L. Gregg. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13-18, 1955.*) *Trans.*

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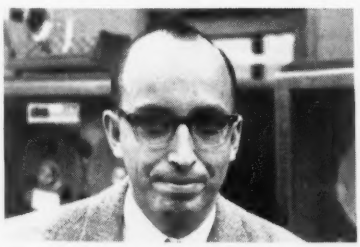

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ASME, Nov., 1956, pp. 1,823–1,828; Discussion, p. 1,829.

Geschichteter Kreiszylinder im Felde periodischer Temperaturschwankungen. Václav Vodička. *ZAMP*, Sept. 25, 1956, pp. 422–427. In German. General analysis of the propagation of heat waves in an infinite, hollow, multilayer cylinder subjected to periodic variations of temperature.

Pressure Drop and Heat Transfer for Coolers and Heat Exchangers. A. Burgdorfer. *Escher Wyss TN 3, TN 2; vol. IV, Rep. Sp.-AK-56-030 (AFOSR TR 56-48) [AD 97090]*, July 21, 1956. 21 pp. Derivation of a relation for pressure-loss problems of heat exchangers and coolers by rearrangement of pressure-drop and heat-transfer formulas and by elimination of the friction factor and heat-transfer coefficient of the surfaces.

VTOL & STOL

VTOL Fixed-Wing Aircraft. Ken. S. Coward. *(IAS Natl. Summer Meeting, Los Angeles, June 18–21, 1956, Preprint 642.) Aero. Eng. Rev.*, Jan., 1957, pp. 35–39. 10 refs.

Flight Investigation of the Stability and Control Characteristics of a Vertically Rising Airplane Research Model with Swept or Unswept Wings and x- or +-Tails. Robert H. Kirby. *U.S., NACA TN 3812*, Oct., 1956. 30 pp.

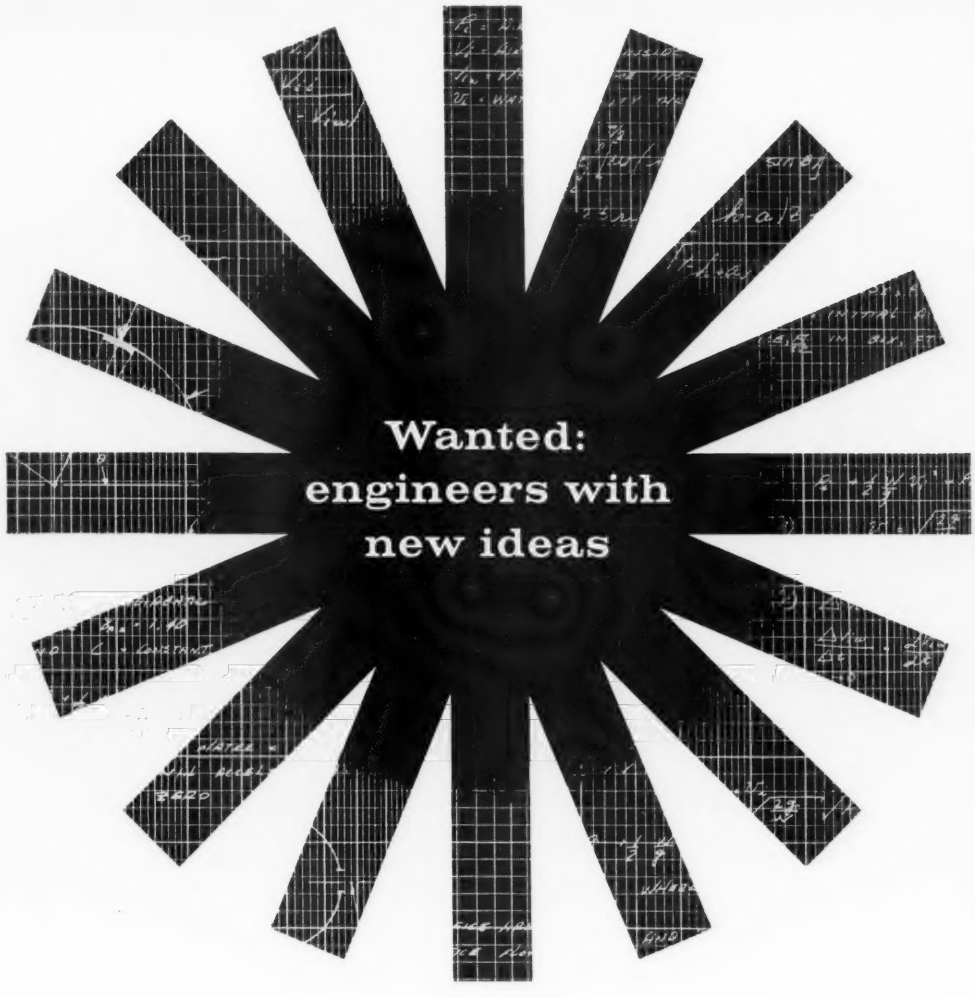
Wind Tunnels & Research Facilities

Condensation Effects and Air Drying Systems for Supersonic Wind Tunnels. J. J. Smolderen. *NATO AGARDograph 17*, July, 1956. 79 pp. 38 refs. Analysis of various aspects of the condensation problem. The phenomenon of condensation effects and the resulting flow disturbances are studied, and an investigation is made of the possibility of complete removal of these effects.

The Effect of a Simple Throat Distortion on the Downstream Flow in a Hypersonic Wind Tunnel Nozzle. R. E. Oliver and B. E. Cummings. *GALCIT Memo. 34*, Oct. 1, 1956. 15 pp. Experimental investigation showing that the magnitude of the effect produced by the throat distortion is approximately that predicted by one-dimensional isentropic flow relations.

Theoretical and Experimental Investigation of the Effect of Tunnel Walls on the Forces on an Oscillating Airfoil in Two-Dimensional Subsonic Compressible Flow. Harry L. Runyan, Donald S. Woolston, and A. Gerald Rainey. *U.S., NACA Rep. 1262*, 1956. 21 pp. 13 refs. Supt. of Doc., Wash., $0.25.

Calibration of the Flow in the Working Section of the 3ft × 3ft Tunnel, National Aeronautical Establishment. D. E. Morris. *Gt. Brit., ARC CP 261 (ARC TR Aero. 2336*, Sept., 1954), 1956. 43 pp. BIS, New York, $1.08. Measurements of pitot and static pressures and flow direction made with Mach Number 1.4, 1.6, 1.8, and 2.0 nozzles in order to show the general nature of flow distribution and the characteristics of the flow.



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AERODYNAMICS

Wing Theory. A. Robinson and J. A. Laurmann. Cambridge, At the University Press; New York, Cambridge University Press, 1956. 569 pp., diagrs., tables. $13.50.

The present book includes the "classical" theory of airfoils at low speeds in two and three dimensions, as well as some of the latest developments in supersonic flow. The problems of stability and flutter are discussed in a separate chapter dealing with unsteady airfoil theory. The hydrodynamic foundations of the subject are developed from first principles. The material to a large extent is based upon lectures given at the College of Aeronautics, Cranfield, and at the University of Toronto. Specifically suitable as a textbook for advanced courses, the book is more generally intended for all those in industry, at universities, or at research laboratories, who are interested in airfoil theory for either practical or theoretical reasons. The pursuit of the work requires a sound knowledge of the calculus and of the theory of functions of a complex variable. Detailed references are given whenever special functions such as Legendre polynomials or Bessel functions arise in the analysis. Further aids include a Bibliography, Author and Subject Indexes, and a List of Principal Symbols used in the discussions.

Dr. Robinson is Associate Professor of Mathematics, University of Toronto; Mr. Laurmann is Research Engineer, University of California, Berkeley.

Gas Dynamics of Cosmic Clouds; A Symposium Held at Cambridge, England, July 6–11, 1953. International Union of Theoretical and Applied Mechanics and International Astronomical Union. Published with Financial Assistance from UNESCO. (I.A.U. Symposium Series, Symposium No. 2.) Amsterdam, North-Holland Publishing Company; New York, Interscience Publishers, Inc., 1955. 247 pp., illus., diagrs. $5.75.

Contents: (1) Opening Address, G. I. Taylor. *Part 1, The Observational Data.* (2) The Observational Background of Cosmical Gasdynamics, R. Minkowski. (3) Extragalactic Stellar Systems, A. Blaauw. (4) Information on Velocity and Density Distribution in the Interstellar Gas Derived from Absorption Lines and 21-cm Radiation. (5) Photographic Studies of Southern Emission Nebulae, B. J. Bok; Observational Features in Carina of Interest for Dynamical Theories of Interstellar Clouds and Stellar Evolution, Dorrit Hoffleit; A Preliminary Classification System for Hα-Emission Nebulae, B. J. Bok and C. M. Wade. (6) Certain Peculiar Structures in Interstellar Clouds, G. Shajn. (7) Characteristics of Some Diffuse Nebulae in the Magellanic Clouds, A. D. Thackeray. (8) A Survey of Problems and Suggested Solutions, H. C. van de Hulst.

Part 2, Physical Conditions of the Interstellar Gas. (9) The Electrical Conductivity of the Interstellar Gas, A. Schluter. (10) Discussion on Electrical Conductivity in Gas Dynamics. (11) The Energy Balance of the Interstellar Medium, M. P. Savedoff. (12) The Heating and Cooling of Interstellar Gas Clouds, F. D. Kahn. (13) On the Formation of Condensations in a Gaseous Nebula, H. Zanstra. (14) The Forbidden Line Spectra of Gaseous Nebulae, M. J. Seaton. (15) Discussion on Condensation and Temperature Regulation in Interstellar Gas Clouds.

Part 3, Shock Waves and Collision Problems. (16) Experiments on the Radiation and Ionization Produced by Strong Shock Waves, A. Kantrowitz. (17) Discussion on Shock Waves and Rarefied Gas Dynamics. (18) Radiative and Collisional Excitation, R. Minkowski. (19) Discussion on Luminous Edges and Collisional Excitation. (20) The Collision of Two Highly Ionized Clouds, F. D. Kahn.

Part 4, Turbulence and Magnetic Fields in a Compressible Gas. (21) Turbulence and Magnetic Fields, G. K. Batchelor. (22) The Effect of Compressibility on Turbulence, M. J. Lighthill. (23) Internal Motion Observed in Emission Regions, G. Courtès. (24) Discussion on the Measurement of Turbulence in Nebulae. (25) Remarks Concerning Interstellar Magnetic Fields, L. Biermann. (26) Discussion on Interstellar Magnetic Fields.

Part 5, Formation of Cosmic Clouds and Galaxies. (27) Preliminary Remarks on the Dynamics of the Interstellar Medium, A. Schluter. (28) Outline of a Theory on the Origin and Acceleration of Interstellar Clouds and O-Associations, J. H. Oort. (29) Discussion on the Expansion of Cosmic Clouds and on Luminous Fronts. (30) On the Motion of H I and H II Regions, E. Schatzman and F. D. Kahn. (31) Problems Connected with the Origin of Spiral Arms, C. F. von Weizsäcker. (32) Contribution to the Turbulence Theory of Galaxies, S. von Hoerner. (33) A Model for the Formation of Galaxies, D. W. Sciama. (34) Discussion on Turbulence in Galaxies. (35) On Contraction in Cosmic Gaseous Masses, F. Hoyle.

Part 6, Accretion Problems. (36) Motion of Stars Through Clouds: Accretion, W. H. McCrea. (37) Étude Physique de l'Accrétion, E. Schatzman. (38) General Discussion on Accretion Processes.

Part 7, Gas and Dust in the Interstellar Medium. (39) On the Mass Balance of the Interstellar Medium, L. Biermann. (40) The Relation Between Dust and Gas in Interstellar Clouds, M. P. Savedoff. (41) Remarks on the Constancy of the Ratio Between Gas and Dust in Interstellar Space, B. J. Bok.

Part 8, Conclusions. (42) Summary of the Aerodynamical Aspects of the Symposium, J. M. Burgers. (43) Concluding Remarks on Turbulence in the Interstellar Gas, T. Gold. (44) Final General Discussion.

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Statements and opinions expressed in Book Reviews are to be understood as individual expressions and not necessarily those of the Institute.

DOCUMENTATION

The Layout of Technical Reports. Edited by A. H. Holloway. Presented at the Seventh Meeting of the Documentation Committee, August, 1956, Brussels. (NATO AGARD Specification No. 1.) Paris, AGARD; Washington, Distributed in United States by NACA, 1956. 22 pp.

Recommendations by the Documentation Committee for size, markings on cover and title page, contents list, pagination, notation, abstract, list of references, tables, illustrations, appendices, and index cards in technical reports. Notes are included on the application of the recommendations to bound books and to periodicals. Appendices give proposals to I.S.O. for minimum bibliographical references, examples of abbreviations of titles of periodicals, and cataloger's notes.

ELECTRONICS

Radio Telemetry. Myron H. Nichols and Lawrence L. Rauch. 2nd Ed. New York, John Wiley & Sons, Inc., 1956. 461 pp., illus., diagrs., tables. $12.

This treatment on the theory, methods, and techniques of radio telemetry consists of material gathered together from published papers and reports, original contributions by the authors, both of whom are Professors of Aeronautical Engineering, University of Michigan. The first edition was privately published by the authors in 1954 in compliance with a USAF contract as a volume in the Air Research Series and for use in their teaching activities. The work contains both the practical and the theoretical considerations involved in the design and development of new equipment and discusses better utilization of available equipment. Changes in the second edition include rearrangement of material, correction of errors, an enlarged bibliography, the addition of material covering telemetry systems in current use or development, and the inclusion of new Appendixes, a Glossary, and an Index.

Contents: Part 1, Methods. (1) Introduction and Historical Background. (2) Methods of Radio Telemetry. (3) Noise and Errors in Telemetry: General. (4) Some Elements of Communication. (5) Frequency-Division Multiplexing. (6) Time-Division Multiplexing. (7) Time-Division Systems without Interpolation. (8) Double Multiplexing. (9) Data Interpretation. (10) Radio Links for Telemetry. (11) Comparison of Multiplexing Methods. (12) Instruments for Radio Telemetry. *Part 2, Foundations.* (13) Modulation and Multiplexing. (14) Frequency Analysis. *Part 3, Techniques.* (15) Frequency-Division Radio-Telemetering Systems. (16) Time-Division Radio-Telemetering Systems. (17) Data Reduction. (18) Remote Control Radio Command Links. *Part 4, Appendices.*

Advances in Electronics and Electron Physics, Vol. 8. Edited by L. Marton. New York

Aeronautical

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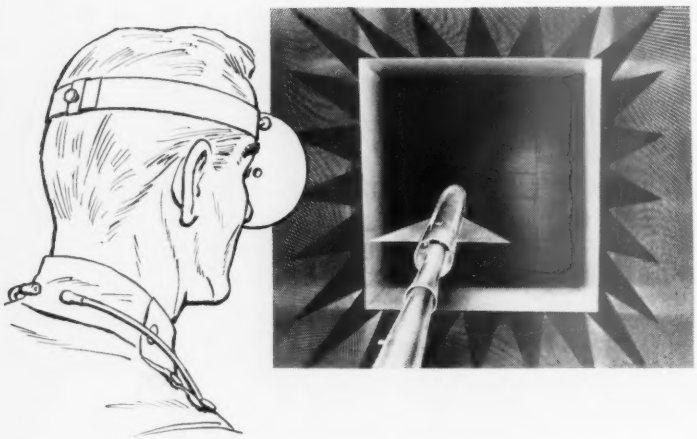

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Academic Press, Inc., 1956. 562 pp., diagrs. $13.

Contents: Some New Applications and Techniques of Molecular Beams, John G. King and Jerrold R. Zacharias. Field Emission, W. P. Dyke and W. W. Dolan. Mass Spectroscopy, Larkin Kerwin. Amplitude and Time Measurement in Nuclear Physics, E. Baldinger. Pulse Amplitude Analysis, J. L. W. Churchill and S. C. Curran. Electron Guns and Focusing for High-Density Electron Beams, Charles Susskind. On the Electrical Life of an Oxide-Cathode Receiving Tube, G. H. Metson. Viewing Storage Tubes, M. Knoll and B. Kazan. Magnetron Mode Transitions, E. C. Okress.

HIGH-SPEED FLIGHT

High Speed Flight Information for Pilots: Including Supplement No. 1. Prepared by Special Devices Center, Office of Naval Research, and by Jackson & Moreland, Engineers, at the request of the Chief of Naval Operations. Rev. Ed. (NAVEXOS P-960.) Washington, Office of Technical Services, March, 1955. 246 pp., illus., diagrs. $6.25, PB-121331.

This is a handbook of general information concerning the phenomena of high-speed flight and is intended primarily for those pilots and air crews who have not yet made the transition from propeller-driven planes to jets. The information presented revolves about the two main considerations in the development of modern high-speed military aircraft—design limits of aircraft and the all-important tolerance limits of the human body.

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MATERIALS

Stress Corrosion Cracking and Embrittlement; A Symposium Arranged by the Corrosion Division of the Electrochemical Society, Boston, October, 1954. Edited by William D. Robertson. New York, John Wiley & Sons, Inc., 1956. 202 pp., illus., diagrs. $7.50.

Contents: The Phenomena and Mechanism of Stress Corrosion Cracking, Julius J. Harwood. The Structure of Grain Boundaries, Bruce Chalmers. Structural Factors Associated with the Stress Corrosion Cracking of Homogeneous Alloys, W. D. Robertson. Stress Corrosion Cracking in Homogeneous Alloys, L. Graf. Metallurgical Aspects of Stress Corrosion Cracking in Aluminum Alloys, E. C. W. Perryman. The Mechanism of Stress Corrosion Cracking Observed in a Magnesium Alloy, D. K. Priest. The Role of Boundary Absorption in Stress Corrosion Cracking, Rudolph Speiser. Stress Corrosion Cracking of Austenitic Stainless Steels in Aqueous Chloride Solutions, T. P. Hoar.

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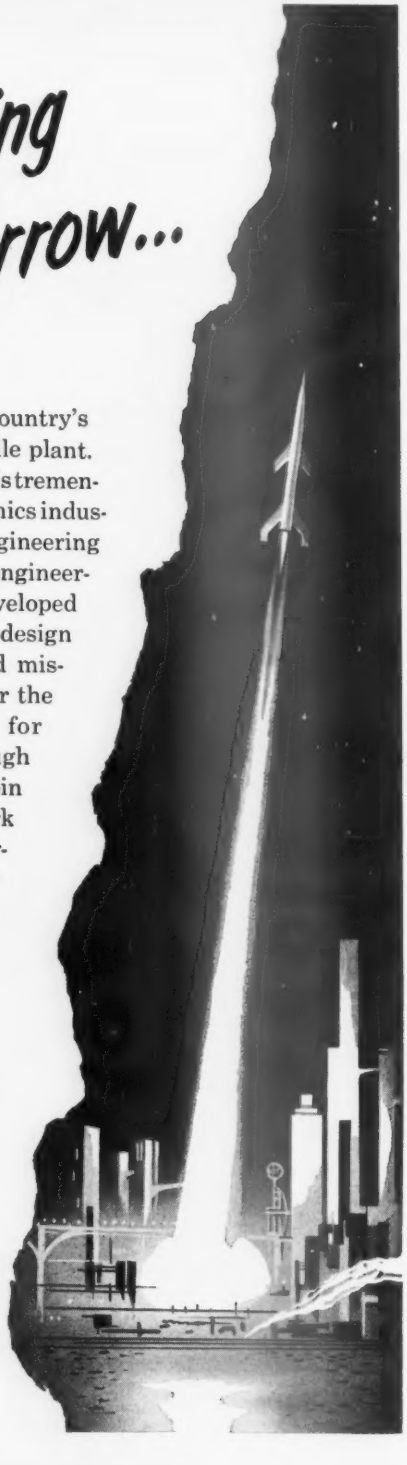

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The Phenomena of Stress Corrosion Cracking in Austenitic Stainless Steels, C. Edeleanu. Stress Corrosion Cracking of Mild Steels, R. N. Parkins. On the Mechanism of Chemical Cracking, U. R. Evans. Hydrogen in Iron and its Alloys, W. R. Heller. Ductility of Steel with Varying Concentrations of Hydrogen, Taiji Toh. Laboratory Techniques for the Investigation of Stress Corrosion Cracking, H. R. Copson.

Corrosion, A Symposium; Held at the University of Melbourne on 28th November–2nd December, 1955. Carlton, Australia, Committee of the Symposium on Corrosion, University of Melbourne, 1956. 609 pp., illus., diagrs., tables. £2 10s.

A collection of papers dealing with methods of minimizing the damage done by corrosion and intended for both science and industry. Participating organizations include Australasian Institute of Mining and Metallurgy (Melbourne Branch), Australian Association for Corrosion Prevention, The Australian Institute of Metals (Melbourne Branch), The Institution of Engineers, Australia (Melbourne Division), The Royal Aeronautical Society (Melbourne Branch), Royal Australian Chemical Institute (Victorian Branch), Royal Melbourne Technical College, Society of Chemical Industry of Victoria, and the University of Melbourne.

Partial Contents: The Mechanism of Corrosion and its Prevention, A. F. Dunbar and H. A. Stephens. Some Aspects of the Kinetics of Corrosion Reactions, G. M. Willis. Applications of Electrochemistry to Corrosion Studies, M. Pourbaix. The Passive Behaviour of Iron, W. T. Denholm. The Mechanism of Anodic Inhibitors of Corrosion: A General Treatment, T. P. Hoar. Corrosion and Stress, U. R. Evans. Design and Interpretation of Corrosion Tests, F. L. LaQue. Biological Organisms and Corrosion Processes, C. D. Parker. The Oxidation of Metals, T. Mills. Temporary Corrosion Preventives, E. C. Kuster. Volatile Corrosion Inhibitors, A. B. Cox and E. C. Kuster. Some Practical and Theoretical Aspects of the Use of Corrosion Inhibitors in Cooling Systems, R. N. Ride. Observations on Corrosion Protection of Airframe Components, H. E. Arblaster and P. F. F. Thompson. Corrosion Problems in Nuclear Reactors, K. F. Alder.

Progress in Metal Physics, Vol. 6. Edited by Bruce Chalmers and R. King. London, New York, Pergamon Press, Ltd., 1956. 354 pp., illus., diagrs., tables. $12.

Contents: The Effect of Hydrostatic Pressure on the Electrical Resistivity of Metals, A. W. Lawson. The Filamentary Growth of Metals, H. K. Hardy. The Austenite: Pearlite Reaction, R. F. Mehl and W. C. Hagel. Recent Advances in Knowledge Concerning the Process of Creep in Metals, A. H. Sully. The Mechanism of Evaporation, O. Knacke and I. N. Stranski. Mosaic Structure, P. B. Hirsch.

The Chemistry of Petrochemicals. Melvin J. Astle. New York, Reinhold Publishing Corporation, 1956. 267 pp., diagrs., tables. $6.50.

For those wishing a broad background in the field of petrochemicals and for the technical researcher concerned with the development of new commercial petrochemical products, the present treatise describes the preparation and important chemical reactions of industrial chemicals made directly or indirectly from petroleum hydrocarbons. These chemical descriptions are supplemented by information on reaction conditions, types of catalyst used, special equipment, and other factors necessary for properly carrying out the processes. Discussions also include the results of petrochemical research and the new developments in both theory and practice. The author is Professor of Chemistry, Case Institute of Technology.

Contents: (1) The Petrochemical Industry. (2) Syntheses of Paraffin Hydrocarbons. (3) Reactions of Paraffin Hydrocarbons. (4) Preparation of Olefins. (5) Reactions of Olefins. (6) Polymerization and Alkylation of Olefins. (7) Diolefins. (8) Acetylene. (9) Naphthenes. (10) Aromatic Hydrocarbons. (11) Olefin Oxides. (12) Alcohols and Ethers. (13) Aldehydes

and Ketones. (14) Acids, Acid Anhydrides and Esters. (15) Amines and Nitriles. Index.

METEOROLOGY

Hailstorms of the United States. Snowden D. Flora. Norman, Okla., University of Oklahoma Press, 1956. 201 pp., illus., diagrs., tables. $3.50.

Although there are Government publications containing many instances of hailstorm damage and occasional articles on the phenomenon and its cause appear in scientific journals and in textbooks, there has been no published work that deals comprehensively with the subject. Thirty-two years of service as Section Director of the United States Weather Bureau in Kansas have given the author the experience to write this inclusive general work on the problem of hail. Aspects discussed include oddities and damage of hailstorms, time and reason for their occurrence, forecasting, hail insurance, hazards of hail in each of the 48 states, and the patterns of hail in other countries. Most of the data have been obtained from official sources.

NAVIGATION

Papers Presented at the Fall 1956 RTCA Assembly Meeting, October 22–23, Indianapolis. (Paper 185-56/AS-176.) Washington, Radio Technical Commission for Aeronautics, 1956. 80 pp., illus., diagrs.

Contents: Simulation, Tirey K. Vickers. Air Traffic Control Coordinating Equipment, G. E. Fenimore. The Air Traffic Control Radar Beacon System, D. S. Crippen. Airways Operations Evaluation Center, F. S. McKnight.

NUCLEAR ENERGY

The Physics of Nuclear Reactors; A Conference Arranged by The Institute of Physics in London from July 3–6, 1956. (British Journal of Applied Physics, Supplement No. 5.) London, The Institute of Physics, 1956. 111 pp., illus., diagrs., tables. 25s.

Contents: Scientific Problems in the Development of Nuclear Power, Sir John Cockcroft. The Physics of Advanced Reactors, J. R. Dietrich. Experimental Reactor Physics, P. W. Mummery. The Zero-Energy Fast Breeder Reactor, Zephyr, L. R. Shepherd. Recent Developments in Nuclear Theory, R. E. Peierls. The Effects of Irradiation on the Physical Properties of Solids, A. H. Cottrell. Shielding for Reactors, G. C. Laurence. The Control of Reactors, A. J. Salmon. The Instrumentation of Reactors, W. Macrae. The Role of Chemistry in a Nuclear Energy Project, R. Spence. The Role of Metallurgy in a Nuclear Energy Project, L. Rotherham. The Canadian Research Reactors and Their Uses, W. B. Lewis. The United Kingdom Research Reactors and Their Uses, F. W. Fenning.

PHYSICS

Recent Advances in Science: Physics and Applied Mathematics. Edited by Morris H. Shamos and George M. Murphy. New York, New York University Press; Distributed by Interscience Publishers, 1956. 384 pp., illus., diagrs., table. $7.50.

Contents: Methods of Applied Mathematics, Richard Courant. The Future of Operations Research, Philip M. Morse. Atomic Structure, I. I. Rabi. Microwave Spectroscopy, C. H. Townes. Nuclear Structure and Transmutations, H. A. Bethe. Elementary Particles, V. F. Weisskopf. Electronuclear Machines, Leland J. Haworth. Neutron Physics, Norman F. Ramsey. Transistor Physics, William Shockley. Ferromagnetism, R. M. Bozorth. Cryogenics: Very-Low Temperature Physics and Engineering, F. G. Brickwedde. Physics and the Engineer, Edward U. Condon. Index.

RESEARCH

Research and Development in the U.S. Army, Contractors Guide. Washington, Office of Chief, Research and Development, Dept. of the Army, 1956. 36 pp.

This brochure is designed to inform contractors of general principles and procedures governing Army research and development contracts and to assist them in identifying proper sources of communications on matters related to their interests.

STRUCTURES

Proceedings of the Society for Experimental Stress Analysis, Vol. 14, No. 1. Edited by C. V. Mahlmann and W. M. Murray. Cambridge, Mass., The Society, 1956. 214 pp., illus., diagrs., tables. $6.00.

Contents: A Three-Dimensional Photoelastic Study of Contact Stresses in the Head of a Model of a Railroad Rail, M. M. Frocht. Discussion of Paper Entitled: "A Three-Dimensional Photoelastic Study of Contact Stresses in the Head of a Model of a Railroad Rail," A. J. Durelli. An Experimental Investigation of the Maximum Loads Supported by Elastic Columns in Elastic Compression Tests, B. Erickson, S. V. Nardo, S. A. Patel, and N. J. Hoff. Vibratory Stress Measurements in Multistage Compressor Blading, C. E. Danforth and B. R. Anderson. Modified Theories of Fatigue Under Combined Stress, W. N. Findley and P. N. Mathur. Some Observed Strain Phenomena of a Post-Tensioned Concrete Beam Under Pre-Stress and Flexure, B. L. Dutton. Letter to the Editor: "Alignment Fixture for Calibration of Photoelastic Fringe Value by Tension," E. Wetterstrom. On the Relation Among Stress, Strain and Strain Rate in Copper Wires Submitted to Longitudinal Impact, C. Riparbelli. Fatigue Damage Measured by Deflections of Rotating Beam Specimens, R. G. Crum and E. D'Appolonia. A Fatigue Testing Machine for Reversed Bending and Steady Torque, H. H. Mabie and M. S. Gjesdahl. Automatic Frequency-Control System for a High-Frequency Resonant-Type Fatigue Testing Machine, C. L. Temes. Stress Concentration Factors for Circular Fillets in Stepped Wall Cylinders Subject to Axial Tension, L. H. N. Lee and C. S. Ades. The Study of the Propagation of Stress Waves by Photoelasticity, J. C. Feder, R. A. Gibbons, J. T. Gilbert, and E. L. Offenbacher. Discussion of Paper Entitled: "The Study of the Propagation of Stress Waves by Photoelasticity," A. J. Durelli, W. F. Riley, and J. W. Dally. Experimental Analysis of Aircraft Structures by Means of Plastic Models, G. W. Zender. Horizontal Displacements in a Flexible Two-Hinged Arch, C. L. Monismith and R. W. Clough. Elastic Compliances of Orthogonally Stiffened Plates, W. H. Hoppmann, II. The Concept of Strength from Goodman Diagrams, A. Sniderman. A Vibration Damper for Axial-Flow Compressor Blading, M. P. Hanson. An Apparatus for the Determination of Stress-Strain Properties at High Rates of Strain, R. J. MacDonald, R. L. Carlson, and W. T. Lankford. An Experimental Investigation of the Oblique Impact of Spheres Upon Simply Supported Steel Beams, W. Goldsmith and D. M. Cunningham. Measuring Non-Uniform Residual Stresses by the Hole Drilling Method, R. A. Kelsey. Static and Dynamic Calibration of a Photoelastic Model Material, CR-39, A. B. J. Clark. Observations of Snap-Through Action in Thin Cylindrical Shells Under External Pressure, A. F. Kirstein and E. Wenk, Jr.

Ten-Division Influence Lines for Continuous Beams: Ordinates of Influence Lines and of Moment Curves for Continuous Beams; Influence Coefficients of Cantilever Moments. Georg Anger. 8th Ed., Rev. and Enl. Translated from the German by Charles J. Hyman. New York, Frederick Ungar Publishing Co., 1956. 247 pp., tables. $9.50.

Contents: Three-Moment Equation, Load Coefficients, Formulas for Rapid Computation of Support Moments (Span Moments and Shearing Forces) in Cases of Various Span Loads and Span Lengths for 2,3,4 and More Spans. Three-Moment Equation. Origin of Support Moments. Load Coefficients. Support Moments. Span Moments. Shearing Forces. Reactions. Loading Arrangement for Uniformly Distributed Movable Loads for Obtaining Maxima and Minima. Influence Lines. Influence Lines for Bending Moments. Influence Lines for Shears. Critical Influence Lines for Bending Moments. Fixed-Point Distances. Analysis of Continuous Beams of More than 4 Spans. Influence of the Moment of Inertia on the Calculation of Support Moments. How to Use the Influence-Line Tables for Unequal Moments of Inertia. Beam on 2 Supports. Beam on 3 Supports (2 Spans). Beam on 4 Supports (3 Spans). Beam on 5 Supports (4 Spans). Beam on 6 Supports (5 Spans). Influence Lines for a Central Span in the Case of any Number of Equal Spans.

WIND TUNNELS

Condensation Effects and Air Drying Systems for Supersonic Wind Tunnels. J. J. Smolderen. (AGARDograph No. 17.) Paris, AGARD; Washington, Distributed in United States by NACA, July, 1956. 79 pp., diagrs.

A review of various aspects of the condensation problem for supersonic wind tunnels. *Part 1* is a study of the phenomenon of condensation effects, the resulting flow disturbances, and an investigation of the possibility of condensation effects. A criterion is presented based on certain experimental results. Conditions under which flow disturbances are sufficiently small are also indicated. *Part 2* presents various drying processes in use with detailed treatment of drying by cooling, compression, and absorption. *Part 3* contains a survey of the different measuring devices for the determination of humidity. The report is accompanied by a bibliography and an explanatory list of symbols and terminology. The author is associated with the Centre National d'Etudes et de Recherches Aéronautiques, Brussels. This publication was prepared with the cooperation of the USAF Office of Scientific Research, ARDC.

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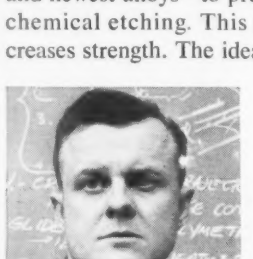

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The only publication of its kind devoted exclusively to the aircraft industry, this CATALOG serves as a valuable buyers' and reference guide to sources and specifications on aircraft materials, parts, and accessories. It is distributed annually to Chief Engineers, Designers, Production Heads, and Purchasing Departments of all leading Aircraft, Aircraft Engine, Instrument, Accessory, and Aircraft Parts Manufacturers; Air Transport Companies; Army, Navy, and Governmental Agencies; Research Organizations; Engineering Libraries; etc.

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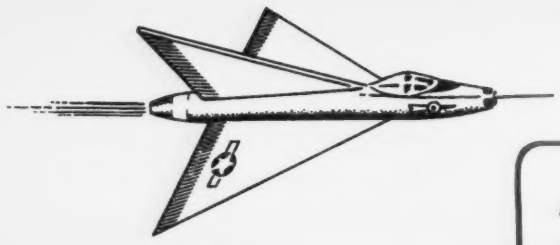

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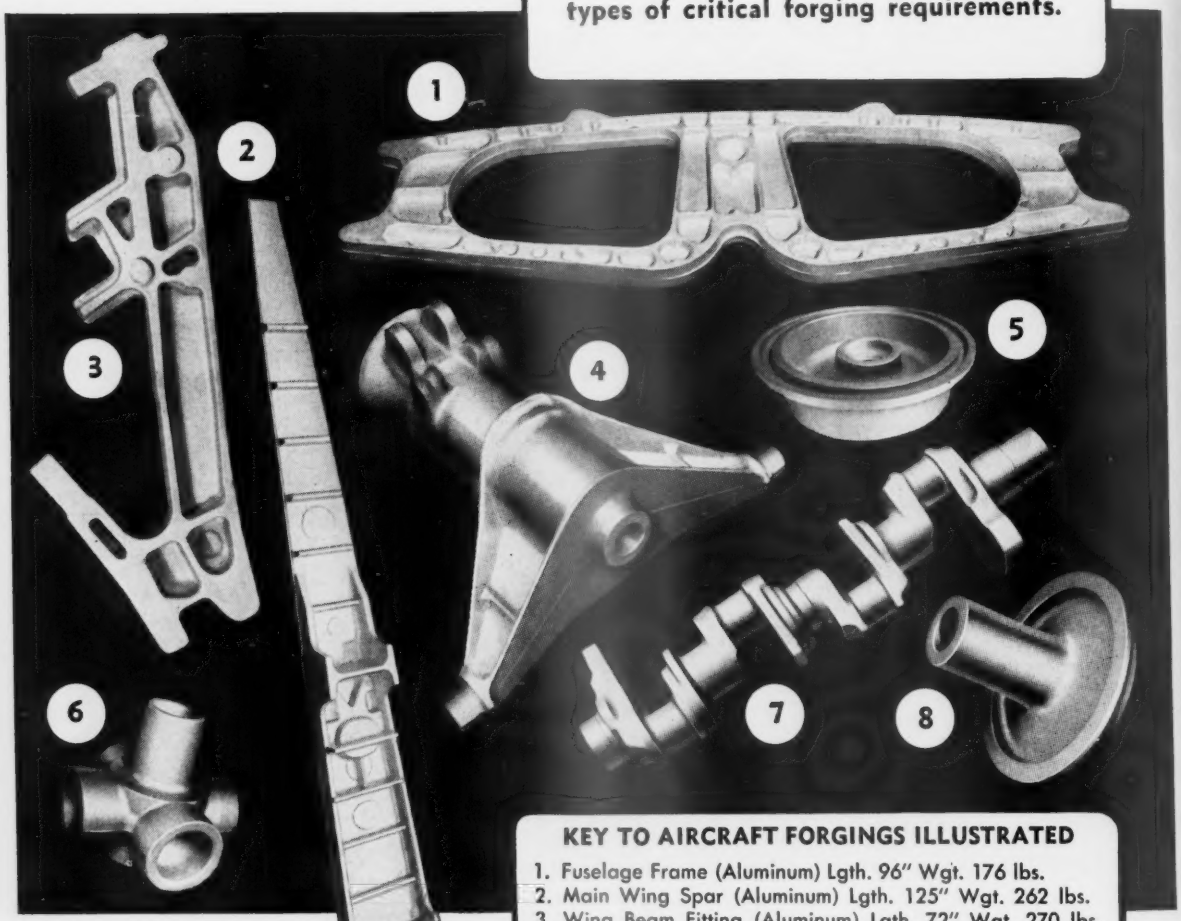

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AIRCRAFT MATERIALS & PROCESSES

Plastic Materials. Bulletin details sizes, properties, and uses of acrylic rods, tubes, and shapes. **Ace Plastic Co., 91-30 Van Wyck Expressway, Jamaica 36, N.Y.**

Metal Hose & Tubing. This 64-page catalog No. G-560 provides design suggestions to assist the engineer to plan flexible metal connector applications. **The American Brass Co., American Metal Hose Div., 666 S. Main St., Waterbury 20, Conn.**

Copper Tape. Available for the first time in thicknesses as low as 0.00015 in. in pilot lot quantities. **American Silver Co., Inc., 36-07 Prince St., Flushing 54, N.Y.**

Metal Laminates. These laminates are combinations of two or three metals permanently and metallurgically bonded together to form one "sandwich." **Bridgeport Brass Co., 30 Grand St., Bridgeport 2, Conn.**

Silicone Products. 12-page 1957 reference guide. **Dow Corning Corp., Midland, Mich.**

Plastics Molding Bulletin. Describes specialized injection molding of tiny thermoplastic parts. **Gries Reproducer Corp., 400 Beechwood Ave., New Rochelle, N.Y.**

Brass, Bronze, & Nickel Silver Casting Alloys. 17 in. by 22 in. wall chart details information regarding 37 standard alloys. **Henning Bros. & Smith, 91-127 Scott Ave., Brooklyn 37.**

Flame-Blown Glass Fiber Insulations. For thermal and acoustical applications. **L.O.F. Glass Fibers Co., 1810 Madison Ave., Toledo 1.**

Nylatron "GS" Nylon Molding Powders. Features high wear resistance, low dry running friction, and dimensional stability. **National Polymer Products, Inc., Reading, Pa.**

Circular Slide-Rule Type Calculator. This calculator facilitates determination of the weight of springs made from given sizes of round wire or flat stock. **National-Standard Co., Niles, Mich.**

LPO Paint Remover. A nonflammable remover designed to remove Epon and other difficult-to-remove paints. Bulletin No. 9. **RPO Chemical Corp., 2727 E. Nine Mile Rd., Hazel Park, Mich.**

AIRCRAFT PARTS & EQUIPMENT

6,000 Psi High Flow Regulator. Maintains a high degree of accuracy with regulated pressure from 0 to 5,000 psi. **Accessory Products Corp., 616 W. Whittier Blvd., Whittier, Calif.**

Pressure Hose Assemblies. Descriptive catalog No. 101. **Aeroquip Corp., Jackson, Mich.**

Timing Mechanism. This mechanism is built on a modular or "building block" principle which permits a wide range of timing intervals and a variety of mechanical or electrical control functions. **Allied Products Div., Hamilton Watch Co., Lancaster, Pa.**

Screw Machine Products. Descriptive 4-page brochure. **Allmetal Screw Products Co., Inc., 821 Stewart Ave., Garden City, N.Y.**

Spring Design. Descriptive 8-page guide. **Associated Spring Corp., Bristol, Conn.**

"Seelbolts" Self-Sealing Bolts. For high-pressure sealing and for applications requiring resistance to heavy vibration. **Automatic & Precision Mfg. Co., 252 Hawthorne Ave., Yonkers, N.Y.**

High-Temperature, High-Pressure "B" Seal. An exclusive lip design which snaps on the flange; permits fast, positive alignment in tight places. **Awica Products, Inc., 2113 Stoner Ave., Los Angeles 25.**

Aircraft-Type Swivel Joints. Descriptive 12-page catalog No. 269-A. **Barco Mfg. Co., 500 N. Hough St., Barrington, Ill.**

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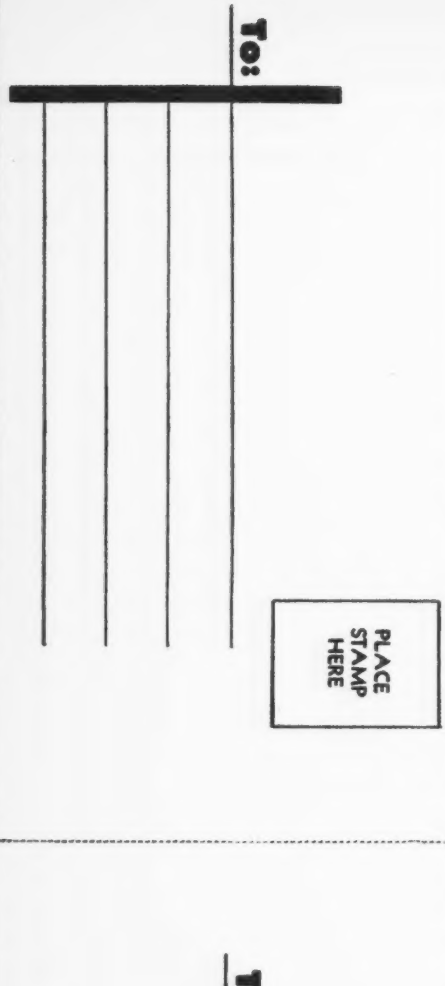

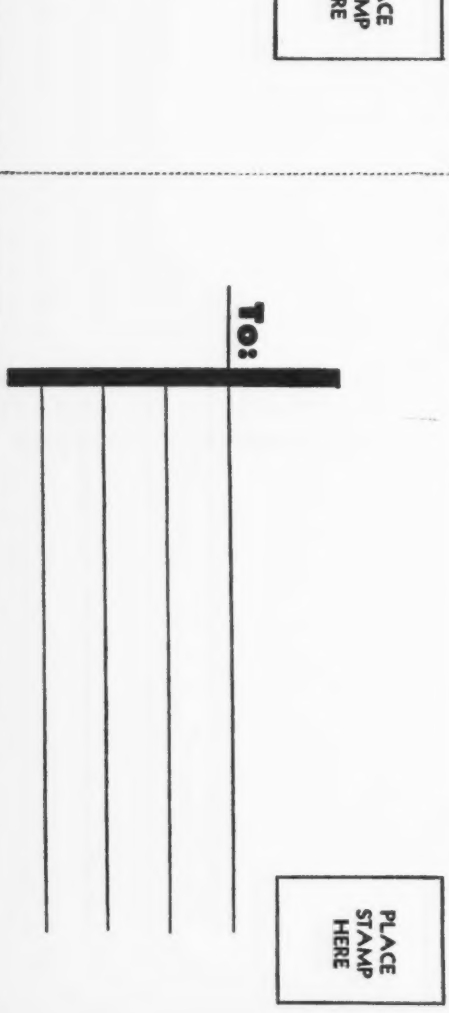

Aircraft Pressure Switches. For switching electrical circuits in response to pressure changes in gases, liquids, and the atmosphere. **The Bristol Co., Waterbury 20, Conn.**

Cargo Tie-Down Fittings. Designed to anchor to aircraft standard floor seat track. **Brown-Line Corp., P.O. Box 45, 215 Airport Sta., Los Angeles 45.**

No. 600 Stainless-Steel Rivet. This rivet has a shear strength of 85,000 psi at 800°F. **Cherry Rivet Div., Townsend Co., Box 2157-Z, Santa Ana, Calif.**

Aircraft Wire Cable. Descriptive 4-page folder. **The Electric-Auto-Lite Co., Port Huron, Mich.**

Piezoelectric Accelerometers. These instruments operate with less than 10 per cent change of sensitivity over the temperature range of −65° to 230°F.; bulletin No. 803-202. **Endevco Corp., 161 E. California St., Pasadena, Calif.**

Cooling Effect Detector. Protects air-borne electronic equipment against inadequate cooling conditions; bulletin No. MC-142. **Fenwal, Inc., Ashland, Mass.**

Folding Service Tray. For aircraft passenger chairs; folds into the back rest when in stowed position. **Hardman Tool & Engineering Co., 1845 S. Bundy Dr., Los Angeles 25.**

Pressure Operated Propellant Valves. Technical bulletin No. 24 describes complete series. **Hydromatics, Inc., Cedar Grove, N.J.**

Motor Operated Shutoff Valves. For high-pressure control functions; handles liquid oxygen, rocket fuels and oxidizers, jet fuels, hydraulic fluids, and high-pressure pneumatics; bulletin No. 23. **Hydromatics, Inc., Cedar Grove, N.J.**

"Dynafocal" Turbine Suspensions. Descriptive 8-page folder No. 505. **Lord Mfg. Co., 1635 W. 12th St., Erie, Pa.**

Utilized Explosive Gas Generators. Designed to provide power for operation of turbines, pressurization of fluids and systems, actuation of piston and expandable rings, and ignition of liquid propellants. **McCormick Selph Associates, 12 Hollister Airport, Hollister, Calif.**

Series 1100 Aircraft Flush Latch. Specially designed rubber gaskets improve latch sealing characteristics at access doors and panels. **Missile-Air, 1616 W. 134 St., Gardena, Calif.**

3-Min. Synchros. For air-borne applications requiring accuracy with minimum bulk and weight. **Norden-Ketay Corp., Commerce Rd., Stamford, Conn.**

Type 5602-02 Low-Speed High-Torque Motor-Gear-Train. Can be operated in temperatures as low as −55°C. **John Oster Mfg. Co., Racine, Wis.**

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Instrument Flight Simulator. Permits natural vision of the instrument panel while cutting off the pilot's outside visibility. **Piper Aircraft Corp., Lock Haven, Pa.**

"Zippertubing" Zipper-Style Plastic Tubing. Can be used to enclose, identify, and protect multiconductor wiring in aircraft. **W. A. Plummer Mfg. Co., 752 S. San Pedro St., Los Angeles.**

Union-Filter Valve Protector. Protects aircraft hydraulic system valves and other precision components. **Purolator Products, Inc., Rahway, N.J.**

Instrument Valve. Features positive nonleak shutoff, O-ring seals, and plastic self-extracting seat. **Robbins Aviation, 1735 W. Florence Ave., Los Angeles 47.**

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"Klixon" Thermo-Snap Thermostat. For applications where maximum shock and vibration resistance are required. **Spencer Thermostat Div., Metals & Controls Corp., Attleboro, Mass.**

"Nylols" Self-Locking Aircraft Screws. Saves assembly time on air frames and air-frame components. **Standard Pressed Steel Co., Jenkintown, Pa.**

"We-Pins" Quick Release Pins. May be used as shear-pins, lock-pins, hinge-pins, and clevis-pins; features a streamlined head design that saves weight, space, and cost; lock-button is activated by a silicone core; holds a shear load of over 3,600 lbs. in 1/4 in. dia. and over 58,000 lbs. in 1 in. dia. **Waldick Engineering Co., P.O. Box 221, Garden City, N.Y.**

Cluster Fittings. Descriptive 44-page catalog entitled *Aircraft Piping and Engrg. Application Manual.* **The Weatherhead Co., 300 E. 131 St., Cleveland.**

ELECTRONIC & ELECTRICAL EQUIPMENT

"Acepot" Subminiature Wire-Wound Potentiometers. Features a resistance range from 10 ohms to 250K and a linearity of ±0.3 per cent. **Ace Electronics Associates, Inc., 103 Dover St., Somerville 44, Mass.**

No. C-150-223 DC-AC Magnetic Amplifier. This unit is adaptable to input signals from d.c. to 1,000 cps with the addition of a reference transformer. **The Ahrendt Instrument Co., 4910 Calvert Rd., College Park, Md.**

500 Series S-Band Cavity Oscillator. For either pulse or continuous wave operation in aircraft, guided missile, and beacon applications. **Amerac, Inc., 116 Topfield Rd., Wenham, Mass.**

Model 253-E Panel Meter. This meter has a scale range of from 0 to 20 microamp. **Assembly Products, Inc., Chesterland, Ohio.**

Series N-9,000 High-Pressure Seals. For shafts which pass through panels or housings and for rotary switches. **Automatic & Precision Mfg. Co., 252 Hawthorne Ave., Yonkers, N.Y.**

Model 1800-0700 Servoamplifier. Designed to receive signals from a synchro-control transformer and to operate a size 15, 60-cycle, 6.1-watt servomotor or equivalent. **M. Ten Bosch, Inc., Pleasantville, N.Y.**

Model BL-536 Multichannel D.C. Amplifier Unit. For applications where limited space is a factor and maximum mobility and flexibility are desired. **Brush Electronics Co., 3405 Perkins Ave., Cleveland 14.**

Type 101C Minimalized Trimmer Potentiometer. Essentially a locking bushing with a potentiometer built inside. **Carter Mfg. Corp., 23 Washington St., Hudson, Mass.**

Adjustable D.C. Power Supply. Output of the unit may be adjusted to provide any voltage between 300 and 500 VDC by means of minor internal changes. **Dressen-Barnes Corp., 250 N. Vinedo Ave., Pasadena, Calif.**

Clutter-Operated Anticlutter Receiver. Designed specifically to complement air-borne radar equipment, this instrument separates and defines radar targets more clearly and saves time and effort for the radar technician. **Allen B. Du Mont Laboratories, Inc., 750 Bloomfield Ave., Clifton, N.J.**

DY-2200 Sweep Oscillator. Covers the 5- to 5,000-cps frequency range in one continuous band. **Dynac, Inc., 395 Page Mill Rd., Palo Alto, Calif.**

Model 13-100-1 Single-Turn Potentiometer. Operating temperatures range from −55° to +100°C.; bulletin No. 64. **Electromath Corp., 190 Henry St., Stamford, Conn.**

Filtered D.C. Power Supply. Descriptive literature. **Electro Products Laboratories, 4500 N. Ravenswood Ave., Chicago 40.**

VG Relay. This relay has a vibration rating at 15*g* from 55 to 2,000 cps; shock is rated at 100*g*. **Elgin National Watch Co., Elgin, Ill.**

Model 2621 Regulated & Filtered Power Supply. For use with Endevco acceleration, vibration, pressure, and force measuring systems. **Endevco Corp., 161 E. California St., Pasadena, Calif.**

4JA60 Series High-Current Silicon Rectifiers. 12-page brochure No. ECG-148A. **General Electric Co., Electronics Park, Syracuse, N.Y.**

Silver & Cadmium Oxide Electrical Contacts. Withstands larger currents than silver or its alloys, without welding or sticking. **Gibson Electric Co., 8305 Frankstown Ave., Pittsburgh 21.**

Hermetically Sealed Potted Switch With Actuator. For use on aircraft and missile applications. **Haydon Switch, Inc., Waterbury, Conn.**

Miniature, Hermetically Sealed Switches. Descriptive catalog No. 5. **Haydon Switch Co., Waterbury, Conn.**

Miniature A.C. Voltmeters. Features expanded scales. **International Instruments, Inc., P.O. Box 2945, New Haven 15, Conn.**

Vacuum Transfer Relay. Operates at 25-kv. voltage. **Jennings Radio Mfg. Corp., P.O. Box 1278, San Jose, Calif.**

Type JGF-RE2 Vacuum Transfer Relay. For antenna transfer switching applications in high-altitude aircraft. **Jennings Radio Mfg. Corp., P.O. Box 1278, San Jose, Calif.**

Synchronous Motor. Designed for incorporation in timers subjected to temperatures up to 150°F.; bearings require no lubrication. **The Lux Clock Mfg. Co., 95 Johnson St., Waterbury, Conn.**

Series 35 Tachometer Take-Off Heads. For use in aircraft test work. **Metron Instrument Co., 432 Lincoln St., Denver 3.**

Model 802 Frequency Meter. Features an increase of frequency range from 2,400- to 10,200-mc. to 2,350- to 10,500-mc. **The Narda Corp., Mineola, N.Y.**

Miniature, Telephone-Type Multicontact Relay. For aircraft, guided missiles, computers, data processing equipment, two-way mobile radio units, etc. **Phillips Control Corp., Joliet, Ill.**

Model B-3 Pulse Generator. This generator has a continuous control of pulse width, pulse delay, and repetition rate up to repetition rates of 1 mc. **Rutherford Electronics Co., 3707 S. Robertson Blvd., Culver City, Calif.**

Cooling Panel. For flushing clean, cooling air through standard 19-in. enclosed relay racks. **Rotron Mfg. Co., Woodstock, N.Y.**

Miniature Tempswitch. For temperature control in cathode tubes and other special and general applications. **Scaico Controls, Inc., Palmyra, N.J.**

Microwave Video Detector Crystal. Operates at temperatures up to 150°C. over a wide frequency range. **Sylvania Electric Products, Inc., 1740 Broadway, New York 19.**

Miniature Time Delay Relay. Available with delay periods from 0.1 to 5.0 sec. **Tempo Instrument Co., 5 Centre St., Hempstead, N.Y.**

Miniature Shielded Thermocouples. Descriptive 6-page bulletin. **Thermo Electric Co., Inc., Saddle Brook, N.J.**

2-Pole Subminiature Relays. The smaller of the two measures 3/4 in. wide by 27/32 in. in length to the flange; the larger 2 PDT in the S-310 subminiature measures 3/4 in. wide to $1^{19}/_{32}$ in. to the flange. **U.S. Relay Co., 1744 Albion St., Los Angeles.**

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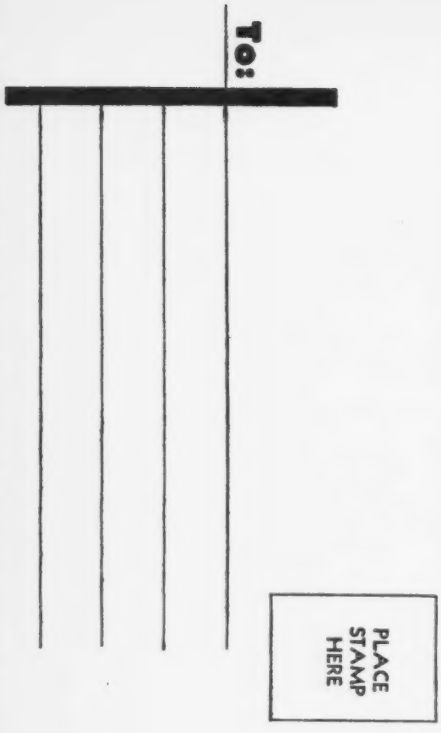
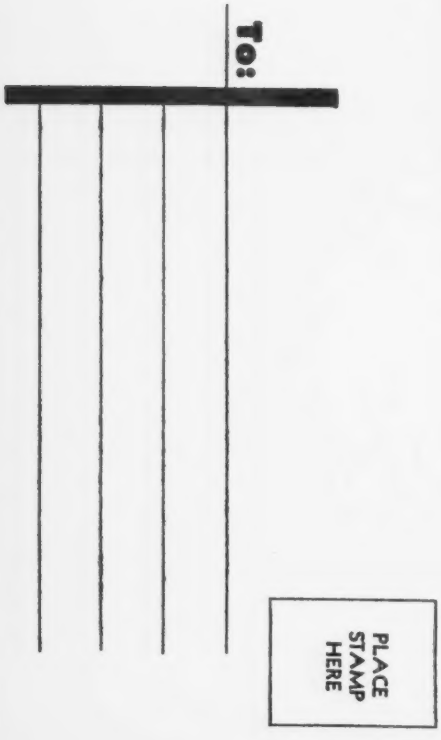




PRODUCTION & MAINTENANCE EQUIPMENT

Rubberized Fiber Cushioning. Provides protection for precision parts, electronic tubes, etc., against breakage or damage during shipment. **Greenwood Packaging Supply Co., 859 Summer Ave., Newark 4, N.J.**

Industrial Periscope. 4-page catalog describes instrument used for the remote observation of inaccessible places and for the study of hazardous processes from a safe viewing distance. **Lenox Instrument Co., 2010 Chancellor St., Philadelphia 3.**

Portable, Self-Feeding Automatic Power Screw Driver. This tool drives screws automatically at any angle and as fast as the operator can pull the trigger. **Shakeproof Div., Illinois Tool Works, St. Charles Rd., Elgin, Ill.**

RESEARCH & TEST EQUIPMENT

Miniature & Standard Temperature & Pressure Sensing Instruments. 18-page bulletin outlines use and specifications of various products, including pressure probes, thermocouples, connectors, and termination fittings. **Aero Research Instrument Co., 315 N. Aberdeen St., Chicago 7.**

"Radiflo" Atomic Energy Leak Detection System. For use in any leak detection problem whether for positive or negative sealed pressures. **American Electronics, Inc., 655 W. Washington Blvd., Los Angeles 15.**

"Evaporograph" Direct Thermal Imaging Device. Bulletin No. RD515 describes this instrument which is used for locating and monitoring either hot or cold spots. **Baird Associates-Atomic Instrument Co., 33 University Rd., Cambridge 38, Mass.**

By-Pass Rotameter. Permits measurement of large fluid flow rates in pipe sizes of 2 in. and above; bulletin No. 116. **Brooks Rotameter Co., Lansdale, Pa.**

High-Speed Printer-Plotter Device. Translates the language of an electronic computer into easily read printed records as fast as the "brain" can calculate. **Burroughs Corp., Detroit 32.**

Electronic Counting, Timing, & Controlling Instruments. Short form catalog. **Computer-Measurements Corp., 5528 Vineland Ave., North Hollywood, Calif.**

26-V D.C. Power Supply. Descriptive 2-page bulletin No. 1570. **Consolidated Electrodynamics Corp., 300 N. Sierra Madre Villa, Pasadena, Calif.**

Magnetic Tape Recording & Playback System. Descriptive 26-page bulletin No. 1561B. **Consolidated Electrodynamics Corp., 300 N. Sierra Madre Villa, Pasadena, Calif.**

Digital & Analog Equipment. 4-page folder lists company's facilities. **Cook Electric Co., 2700 N. Southport Ave., Chicago 14.**

Series 140 Force Transducers. Descriptive 2-page bulletin No. 140. **Daytronic Corp., 216 S. Main St., Dayton 2, Ohio.**

Model 400A Differential Transformer Amplifier. For use with all differential transformer transducers in dynamic and static measurement of motion, force, weight, pressure acceleration, and similar quantities. **Daytronic Corp., 216 S. Main St., Dayton 2, Ohio.**

Portable "An-Eck-Oic" Chamber. This echo-free chamber is designed for scaled-down testing of small microphones, signal devices, miniaturized electronic and mechanical equipment, etc. **Eckel Corp., 155 Fawcett St., Cambridge, Mass.**

Indicating, Recording, Controlling, & Transmitting Instruments. 32-page catalog No. 2 describes instruments for measurement of flow, pressure, and density. **Fischer & Porter Co., 907 Jacksonville Rd., Hatboro, Pa.**

Potentiometer-Type Accelerometer. Measures lateral accelerations in two mutually perpendicular planes. **Genisco, Inc., 2233 Federal Ave., Los Angeles 64.**

Mechanical Force Gages. Bulletin No. 705c gives complete specifications for eighteen direct reading gages. **Hunter Spring Co., 1 Spring Ave., Lansdale, Pa.**

Thermopiles. 12-page brochure describes conversion of infra-red energy into electrical energy suitable for amplification and measurement. **Jarrell-Ash Co., 26 Farwell St., Newtonville 60, Mass.**

Model 955 Electronic Thickness Tester. Determines the thickness of plating and other metallic coatings deposited over various metals and nonmetallic base materials. **Kocour Co., 4800 S. St. Louis Ave., Chicago 32.**

Systems Evaluation Test Equipment. This 22-page brochure explains the philosophy of system test equipment for military electronic systems. **Link Aviation, Inc., Binghamton, N.Y.**

Model 80A Yaw Rate Table. Tests gyros and gyroscopic switches under environmental temperature conditions of −67° to 187°F. and altitude conditions of sea level to 60,000 ft. **Micro Gee Products, Inc., Box 1005, 6100 W. Slauson Ave., Culver City, Calif.**

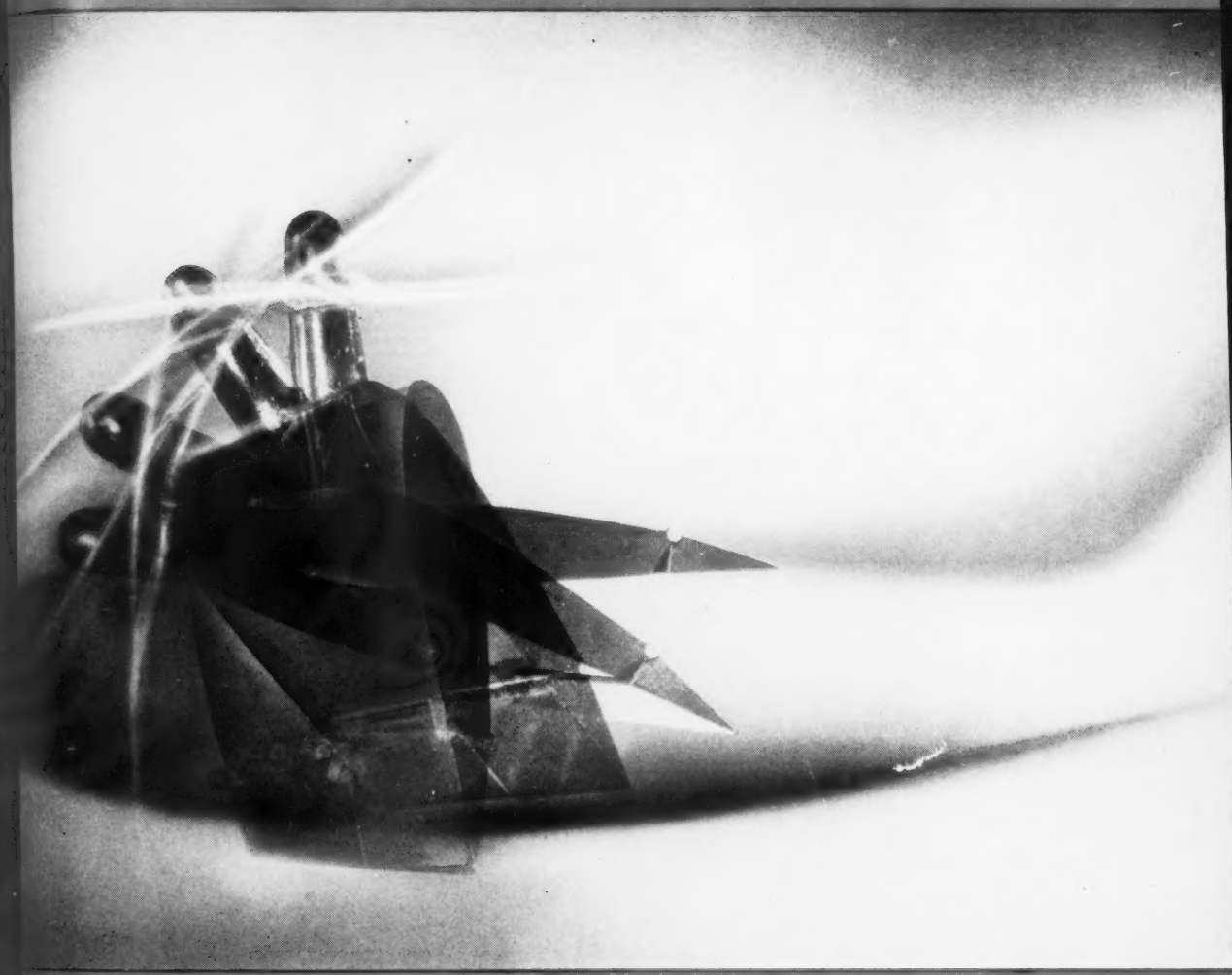
Digital Ohmmeters. Measures a wide range of resistance values, with very small currents passed through the test resistance. **Non-Linear Systems, Inc., Del Mar, Calif.**

Electromatic Universal Testing Machines. Descriptive 40-page bulletin. **Tinius Olsen Testing Machine Co., Dept. 5701, Easton Rd., Willow Grove, Pa.**

Wings of old take on a new turn to bring true VTOL flight closer. Vertol research now takes on one of the most advanced assignments of the decade—high speed aircraft with vertical takeoff and landing capability.

Project: Vertol is now developing aircraft types which will fly as fast, as high, as far, as today's transports yet are able to take off and land at 0 mph forward speed.

Qualifications: Vertol's long-established leadership in the helicopter industry, Vertol's impressive research and development record in all aspects of vertical flight.



Progress: Vertol is currently developing a flying test bed for the Army under contract with the Office of Naval Research. In this aircraft—a small-scale variant of the larger, more powerful production types to come—a gas turbine drives rotor propellers housed in the wings of the aircraft. To takeoff and land vertically, both wings and rotor propellers pivot straight up; the rotor propellers furnish the necessary lift. At altitude, the wings tilt over into "normal" horizontal position, as the aircraft gathers flying speed; cruise is conventional and fast.

To give tomorrow's planes the universal landing and takeoff characteristics of today's helicopters is the essence of the Vertol "Skyways without Runways" concept.

VERTOL Aircraft Corporation

MORTON, PENNSYLVANIA

Engineers, join Vertol's advanced engineering team!

IN AIR CONDITIONING

WHEN PERFORMANCE COUNTS COUNT ON STRATOS

Turbine wheel from refrigeration unit for Boeing B-52.

N15 Air Cycle Machine for s system often used in fighters.

EA75 Package for Jet Bombers plete System includes tempe regulation, flow and pressure tation and moisture separator

Heli-Rotor compressor and An efficient, rotary positive placement compressor for refrigeration systems.

Performance is the payoff in aircraft air conditioning. Weight size, efficiency and reliability are prime criteria.

Simple air cycle packages for trainers—complex systems for heavy bombers or Century fighters—Freon refrigeration systems—for any of these the aircraft engineer knows he can count on Stratos. One of the first to produce aircraft air conditioning, Stratos has designed, developed and delivered complete systems for transports as well as for combat aircraft.

Introduced by Stratos were such advances as evaporative cooling, moisture separators, variable area nozzles, integral controls for temperature, flow and pressure regulation, pressurization rate limitation and many other features.

Faced with a tough air conditioning problem? Look to Stratos for an original, effective solution. Others do.

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A DIVISION OF FAIRCHILD ENGINE & AIRPLANE CORPORATION

Main Plant: Bay Shore, L. I., N. Y.
Western Branch: 1800 Rosecrans Ave.
Manhattan Beach, Calif.
West Coast Office:
1355 Westwood Blvd., Los Angeles, Calif.